Handbook of Environment Centered Gameplay

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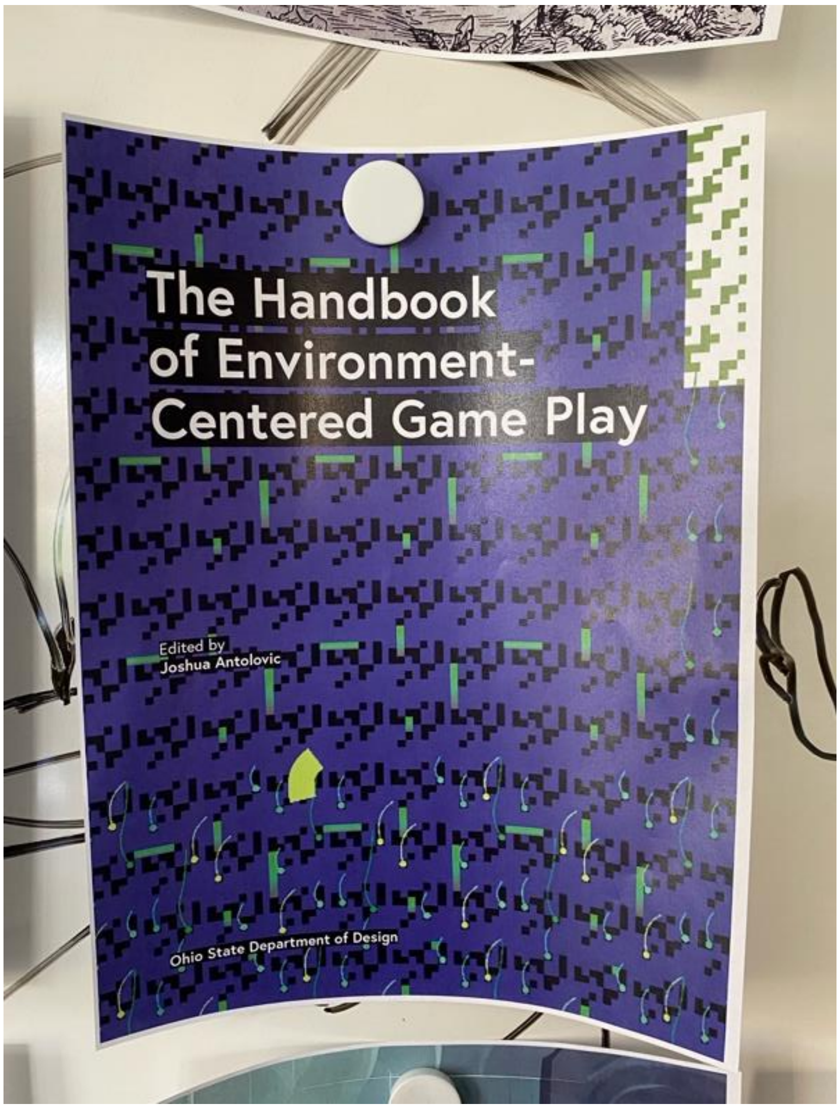

Important Note:

animated GIFs within this handbook will be included at this

link: https://joshantolovic.com/handbook

***GIF* will appear in the caption of the image that is a GIF**

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Introduction

Hello and welcome to the Handbook of Environment Centered Gameplay. Inside is a broad overview that is meant to reflect on the relationship between the digital and the natural. It will not point at correct answers of what environment centered gameplay is or should be. It is meant for you and me to practice a mindset of evaluating and creating media with an ecological lens. I would like to note in the beginning that I will commonly refer to pixels and tiles. The following diagram (Figure 1) visually describes what I am referring to.

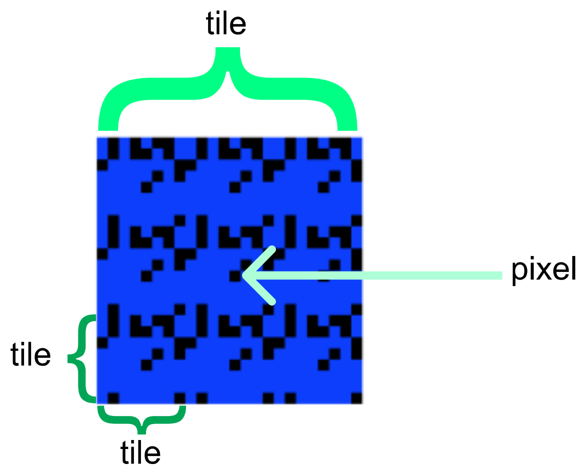


Figure 1

Let's start by thinking of environments and elements of nature within mainstream media. At the core, nature becomes static background fodder as part of the set. Taking a cue from television and film, games use repeating backgrounds or assets to build up faux environmental depth. In some instances, it is used for destroying enemies via elemental spells, a source for endless resource extraction, or a display of power through utter environmental destruction. On the flip side, environments are also portrayed as places to learn, grow, and heal. While some games have made a conscious attempt to center the environment in this way (as seen in this handbook's case studies), there has yet to be a mainstream movement or trend that positions the core of a game's identity on environmental aspects.

The conditions that define environment centered gameplay aren't fixed. I start with the ground whereas someone else might start with clouds. This research handbook will refer to gameplay in which themes involving the environment non-traditionally affect experience. That is to say, the environment steps out of the backdrop and into the foreground, heavily affecting the experience of play. This is radical, given that most game design tools for environment are meant for visual indulgence only. The player is set amongst the landscape, yet the landscape is commonly programmed to be static and/or loop a one-dimensional animation.

The research that has been done to develop digital environments usually has served the purpose of a player controlling a humanoid within an open world landscape. There are numerous computer graphic studies that have been done on how to achieve this task. For instance, branching plant structure algorithms such as L-systems have simplified copying/pasting unique trees. Such procedural tools are being studied and created, yet rarely with interaction in mind. This is in part due to how games are rendered and stored in memory. A computer must render and calculate moving geometry, light, shadows, textures, collisions, player input, and much more all while maintaining performance without lag. The primary goal has been realism.

My design question is this: if we shift our goal from realism and focus on providing new frameworks for environment centered gameplay, what compromises and/or constraints might we benefit from? Video games have a rich history as a medium. Indie developers with little to zero budget benefit from the medium's past and recycle old ideas for new projects. On the opposite end of the game design spectrum are large game studios, catering to the console wars and providing "next level graphics."

Indie developers have the chance to ask much more interesting design questions (at least to me). How have environments been rendered throughout time? What is the difference between travelling in an open world versus a game with a world map and rooms for each location? A side scrolling intuitively has depth which can play at themes for the [ground](#) or [water](#). There is an opportunity for indie designers to turn what was once a memory saving strategy into an aesthetic or mechanic.

Ground as Character(s)

My eyes have always been glued to the ground in one way or another. I note human interference and nature fighting forward. I squeezed lightwells into all my architecture school projects and I only paint below the horizon line. In computation, I see pixels as particles or ground bits. I make to set the ground as character(s). I have opted to make top-down renditions of the ground for game design, which offers what most people call a god-like view. This view allows us to see patterns that might not be viewable from a human perspective. To provide an example, in my GRA work, I took many photos of a ground to test a photogrammetry model of it. It wouldn't be until during post-processing that I would notice streak marks from a motor vehicle on the ground (Figure 2). As you compare Figure 2 from left to right, the analysis for each image depends on the scale from which you view it. I frequently wonder what would happen if the ground was treated with as much respect as the inverse: the heavens.

Figure 2

The ground is typically seen as flat, character-less. Developers, contractors, architects, and dreamers plow through it as though it were waiting to be wiped away. Ironically, what is left is very reminiscent of the CPlane in 3D modeling software such as Rhino. According to McNeel "The CPlane command sets the origin and orientation of the construction plane in the active viewport" (*CPlane | Rhino 3-D Modeling*, n.d.). The CPlane orients the digital ground for what might be built off the supposedly shallow earth. In a silly way, one can see lawns are treated the same as a CPlane. Certain things can belong on it, and anything else must be eliminated. Thus, the complexity of our urban ecologies is as deep as grass, dirt, hedge, tree, weed. With lawn mimicking the CPlane, we choose to revert ourselves back to a blank space. There is an illusion of control that the community partakes in (see Figure 3, a collage and poem I made in 2017).

Everyone
at attention now
houses in formation
salute the mower
as it winds
around the oak
the private pastures
just thick enough
the neighbors are
green with envy
on the other
side of the fence

Figure 3

Ecocriticism

Many games that I've played have relied on fast paced violence to humans or non-human things. One of the first things you might do as Link in *The Legend of Zelda* series is swing your sword at bushes, leaving a stump. Not to fret, if you leave the area and come back, the bush will be right where it was before, as if nothing ever happened. Unfortunately, the real world's resources aren't limitless, even though we often act as though they are. A research question I've begun to craft is: how are ecocritical effects on a player defined and when do they occur? It would be beneficial for game designers to look at ecocritical studies and borrow ideas and concepts to give definition to the effects players have when playing existing games. Many games have accidentally been ecocritical and how it happens is worth analyzing. I will carry plenty of questions on ecocriticism in games and frequently borrow it as a theoretical framework.

Genotype / Phenotype

One key inquiry to make at the outset of creating digital environments is to determine if they are inspired and generated from genotype, phenotype, or a combination of both. In this case, I'm using genotype to describe and render an environment through its quantitative data regarding genetics and chemical makeup. Phenotype on the other hand is in reference to observable traits, viewable to the human eye. Depending on the game design, it is difficult to mimic environments at the cellular level, especially in a computer. A phenotype-based environment can hold its own weight with proper design and consideration. A game designer could create two lists of different macro (phenotype) and micro (genotype) decisions and examine how, when developed and rendered, the digital environment functions and feels. Questions of biological representation and animation strategy will arise. To aid the designer, multiple field observations of different environments from different individuals should be recorded as qualitative data. Certainly, everyone sees ecosystems differently and understands them at different scales. Reviewing the general perception of natural elements and the scale at which they are perceived can be beneficial in creating games that are considered the most eco-driven. The same research might be done for retro digital environments that rely on abstraction to symbolize what would otherwise be dense ecosystems.

I've been adopting the mindset of "think like an ecosystem, design like an ecosystem." Too often the physical environments we inhabit are designed to look pretty. Take for example a parking lot. Trees in parking lots are merely decorative and would be cut down if the roots were to intrude on the asphalt (Figure 4). Sometimes they're planted in mulchy aggregate that is replaced every year or are rooted in a bed of rocks. Referencing the CPlane again, architectural tools erase what was once before, and prevent anything else from growing. This is designing a "pretty" picture. This mindset stretches from parking lots to parks designed by famous landscape architects. A new, simple rule to consider for the design of the physical world might be, if it has an element of nature, what is its ecosystem plan (similarly to how buildings have maintenance plans). This same approach should be considered for digital worlds. Either way, design might facilitate this mindset into a real and tangible process. Our questions would be reframed too. Why does the ground crack? What does it want? How does it heal?

Figure 4 - photo credit: https://ronnysalerno.com/

On Visual

Game designers can utilize low fidelity computer graphics to portray deep environmental narratives. Many indie developers who make pixelated games as a stylistic choice return to static imagery. This isn't bad, nor should it be a short-lived trend. Static pixelated imagery might provide more space in which the player's imagination can operate. As abstract art leaves space for interpretation, ambiguity might allow for subconscious image generation, even if an entire composition is not formed in the mind. The subconscious creation is fluid, without definitive form, just like animation itself. Pixelated tiles can be hand drawn, however with a bit of tooling, the medium naturally lends itself to being algorithmically generated. This avenue expands the possibility of generation and simulation via shaders and the graphics processing unit (GPU). A shader is a computer program that can define how certain graphics should appear on the screen. Shaders typically are written in a unique shading language to be run through the GPU. The GPU is specialized to handle these sorts of tasks, operating methods over many pixels simultaneously rather than one at a time.

Metaphorically, a set of pixels can mimic a physical ground aggregate into a digital format. Each pixel acts as a coordinate while symbolizing a part of what the ground is made of. A pixel with the color code of #AEFFD8 might symbolize an amount of nitrogen. This is an example of how designerly constraints can be applied to visual language. Beyond being limited by hardware, designers can set imaginary constraints that affect game visual, audio, dialogue, mechanic, and whichever other aspects might be imagined. It might be argued that more interesting games are made when constraints are less tied to realism, and instead meet hardware limitations via a unique system that at its core, uses designerly constraints.

On Interaction

Throughout game design history, tilemaps have alleviated computational stress on central processing units (CPU). They apply a method where a single tile is drawn and replicated across different locations, reducing the number of necessary draw calls. A square tile simplifies collision detection algorithms by mapping the environment to a grid. These computer graphics methods enhance the performance and scalability of game worlds, enabling memory for other processes. Environments would become rendered through tilemaps and lose any malleable quality beyond a character stepping over or being blocked by them. In here lies an opportunity to poke around and rearrange the system for state change, behavior, and animated quality.

Grids and tiles offer a structure from which we can detect change. On each draw call, a tile can quickly check each of its neighbors that share a side with it. The tile, which is scalable, could be seen as its own procedural entity. Assuming each tile has the same algorithm applied to it, a numbering system like that of the dewey decimal system holds the tile's DNA. This number updates and serves as parameters for a shader, utilizing the GPU for its ability to process multiple tile's information simultaneously. Each tile checks its neighbor (depending on the set time interval), and updates (again depending on its own time interval) accordingly. With assistance from the GPU, each tile is unique and responsive to its neighbors and/or the player. I've used the word "coordinatism" to describe the systemic quality of the tile, grid, and pixel. While this is a two-dimensional operation, three-dimensional geometry can emerge out of it.

In approaching the question from a data driven perspective, I have questions on whether having biological parameters that are displayed within gameplay can enhance ecosystem immersion. In real life, we aren't seeing data or have a user interface built into our eyes (yet). Having interface elements might take away from the natural interaction of an environment. User interface (UI) study and testing is critical in relation to perception of an ecosystem. A UI could be disruptive when it comes to a player's natural response to learning and adapting to a new environment. On the other hand, a UI could assist in certain areas of instructing the player if designed through visual or audio cues.

On Immersion

This is the area of my practice that is most undefined. There are many questions I ponder. What holds the player? What is the world? Do I need to show all things on screen, or can I allude to them? Is there dialogue? Is it a toy or a game? To resolve the anxiety of unknowing, I've decided to work on my research as though it were a sandbox environment that a player can move things around in. I will be experimenting with a gamut of game design components including audio, reward schedules, and patterns. Audio can alert a player, communicate state changes, and mechanize in different spaces and times. A reward schedule could be tied to audio and offer a bit of something to the player in a sandbox to keep them in the space. The schedule is driven by time, and there may be multiple clocks operating within one experience, such as tree time and game time. For patterns, I've been trying to use the term light patterns as opposed to dark patterns and will try to put together a list of what light patterns might be.

Time as a construct specifically intrigues me, and that human perception of time is mainly wrapped in capitalist ideologies. Slowing down and allowing for nothing grand to occur is a challenge within games which fight to hold player attention. I'd like to pick apart time within games and imagine them with the same amount of slowness as some films or ambient media. This study will aid in creating rules for simulating game environments and creating my definition of immersion. In crafting this definition of immersion, certain types of environment centered interactivity could frustrate players, especially if they are trying to extract something quickly. It would be good for me to read the book *Flow: The Psychology of Optimal Experience* and other related literature to sketch out the optimal experience which does not take players out of play.

Moving forward: learning, thesis, player as gardener and tiles

Along with all the previous mentioned studies that I'd like to conduct over the next two years, there are two projects I'd like to develop that are situated and guided by this handbook. The first is to learn how to develop shaders. By learning shader language, I'll be able to communicate graphical instructions to the GPU. I will need to focus on developing a systemic approach to graphics being connected to interactivity. I plan to take a course or two in the computer science department related to real-time rendering. This will also be my summer self-taught activity. The second project directly follows the first project and for now I'm calling it slow co-design maps. With the use of physical tiles that I'd like to design and fabricate, I would like to position a few grid boards and tiles around campus. I'm curious to know how people organize maps with addition to tile types over time (a scrabble-like for environment maps?). I'd enjoy going to the different areas on campus to take images, add additional tiles, and study the patterns generated. Players might make their own algorithms for tile placement over time. I might even decide to animate tiles (a tile with sprout and a bud turn into a flower tile) and take some away on certain days.

I'm also beginning to imagine what my thesis project could be. It is a continuation and slight adjustment to a project from a year ago, now the design conjecture for topical section 3 in this handbook. The goal of the project is to develop a precedent (with a reasonable pipeline) for visual and interactive mechanics in environment centered-ness media. Critical to the project is aligning the game time to that of true environmental time. The weather, time of day, and season can all synchronize with the player's location. Players can ask what if I placed a rock here and leave it for a few days/nights to see how the space where the rock had been has evolved according to real-time. They can also choose to let the software run as they complete other real-life tasks.

In conclusion, I want to treat players as gardeners and create transient experiences of watching a digital environment shift over time and respond to a player's actions. In some way, shape or form, I hope that what they learn from digital environments can translate back to care and appreciation of real environments. Much of what I learned about environments was through gameplay. I take that this sentiment is true for many who have played games throughout their life, especially if they could not afford to travel and were stuck in suburban or rural areas.

Popular Media

These articles have been gathered to intersect digital and physical landscapes, ecological consciousness, and interactive media.

Starting with *The Lasting Lessons of John Conway's Game of Life*, we look at examples of how a simple example of cellular automata has inspired a wide range of academics and enthusiasts while being a metaphor for life's emergent complexity. There will be a case study for *Conway's Game of Life* in Topical Section 1.

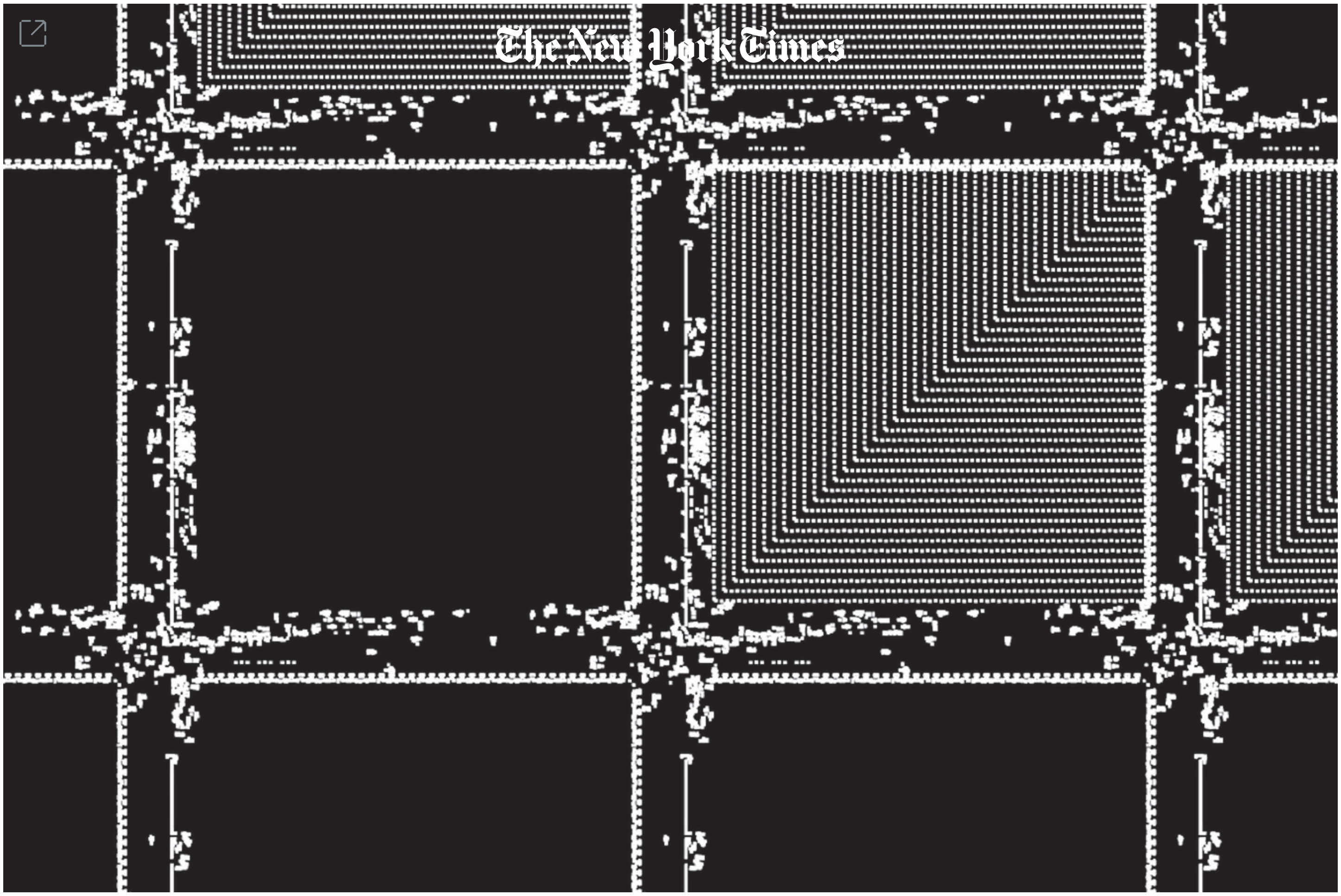
MoMA's *When Video Games Came to the Museum* article orients video games as a legitimate artistic medium, encouraging the broader public to consider the cultural and aesthetic value within the medium. Importantly, MoMA acknowledges that they looked for exemplary examples of interaction design to begin their collection process.

Following this is *Playing Nature: Alenda Chang on Gaming's Role in the Climate Crisis* via the Serpentine Galleries. This interview with Alenda Chang shares Chang's perspective on how games might influence player awareness toward real life ecological challenges. Alenda Chang's book *Playing Nature* is a pivotal book for my research that I read in 6200: Foundation for Graduate Design Studies. I share this interview here as a summary for the book.

Life Along Tree Time reflects on 'tree time' as a concept that encourages slowness to deepen our ecological awareness and disrupt modern time. I have created a design conjecture using this concept of tree time in Topical Section 3.

Lastly, *Tiny Forests With Big Benefits* looks at the potential of small ecological initiatives, inspired by botanist Akira Miyawaki's techniques. I am fond of nature growing in the crevices of society and see this as opportunity to regrow forests. Games themselves have pockets of nature which Alenda Chang calls mesocosms.

Together these articles share my interests and show how I’m beginning to develop my conceptual frameworks with an environment centered mindset.



"Life in Life," from a short documentary on the Game of Life by Alan Zucconi, a London-based lecturer and science communicator.

The Lasting Lessons of John Conway's Game of Life

Fifty years on, the mathematician's best known (and, to him, least favorite) creation confirms that "uncertainty is the only certainty."

Share full article 98

By Siobhan Roberts

Dec. 28, 2020

In March of 1970, Martin Gardner opened a letter jammed with ideas for his Mathematical Games column in Scientific American. Sent by John Horton Conway, then a mathematician at the University of Cambridge, the letter ran 12 pages, typed hunt-and-peck style.

Page 9 began with the heading "The game of life." It described an elegant mathematical model of computation — a cellular automaton, a little machine, of sorts, with groups of cells that evolve from iteration to iteration, as a clock advances from one second to the next.

Dr. Conway, who died in April, having spent the latter part of his career at Princeton, sometimes called Life a "no-player, never-ending game." Mr. Gardner called it a "fantastic solitaire pastime."

The game was simple: Place any configuration of cells on a grid, then watch what transpires according to three rules that dictate how the system plays out.

Birth rule: An empty, or "dead," cell with precisely three "live" neighbors (full cells) becomes live.

Death rule: A live cell with zero or one neighbors dies of isolation; a live cell with four or more neighbors dies of overcrowding.

Survival rule: A live cell with two or three neighbors remains alive.

With each iteration, some cells live, some die and "Life-forms" evolve, one generation to the next.

Among the first creatures to emerge was the glider — a five-celled organism that moved across the grid with a diagonal wiggle and proved handy for transmitting information. It was discovered by a member of Dr. Conway's research team, Richard Guy, in Cambridge, England. The glider gun, producing a steady stream of gliders, was discovered soon after by Bill Gosper, then at the Massachusetts Institute of Technology.

John Horton Conway, investigating "Life" in 1974. Kelvin Brodie/The Sun News Syndication

"Because of its analogies with the rise, fall and alterations of a society of living organisms, it belongs to a growing class of what are called 'simulation games,'" Mr. Gardner wrote when he introduced Life to the world 50 years ago with his October 1970 column.

Life swiftly eclipsed Dr. Conway's many other mathematical accomplishments, and he came to regard his missive to Mr. Gardner as "the fatal letter."

The Game of Life motivated the use of cellular automata in the rich field of complexity science, with simulations modeling everything from ants to traffic, clouds to galaxies. More trivially, the game attracted a cult of "Lifenthusiasts," programmers who spent a lot of time hacking Life — that is, constructing patterns in hopes of spotting new Life-forms.

To mark the 50th anniversary, the ConwayLife.com community — which hosts the LifeWiki, with more than 2,000 articles — created an Exploratorium, a large, explorable stamp-collection pattern.

Patterns that didn't change one generation to the next, Dr. Conway called still lifes — such as the four-celled block, the six-celled beehive or the eight-celled pond. Patterns that took a long time to stabilize, he called methuselahs.

The tree of Life also includes oscillators, such as the blinker, and spaceships of various sizes (the glider being the smallest).

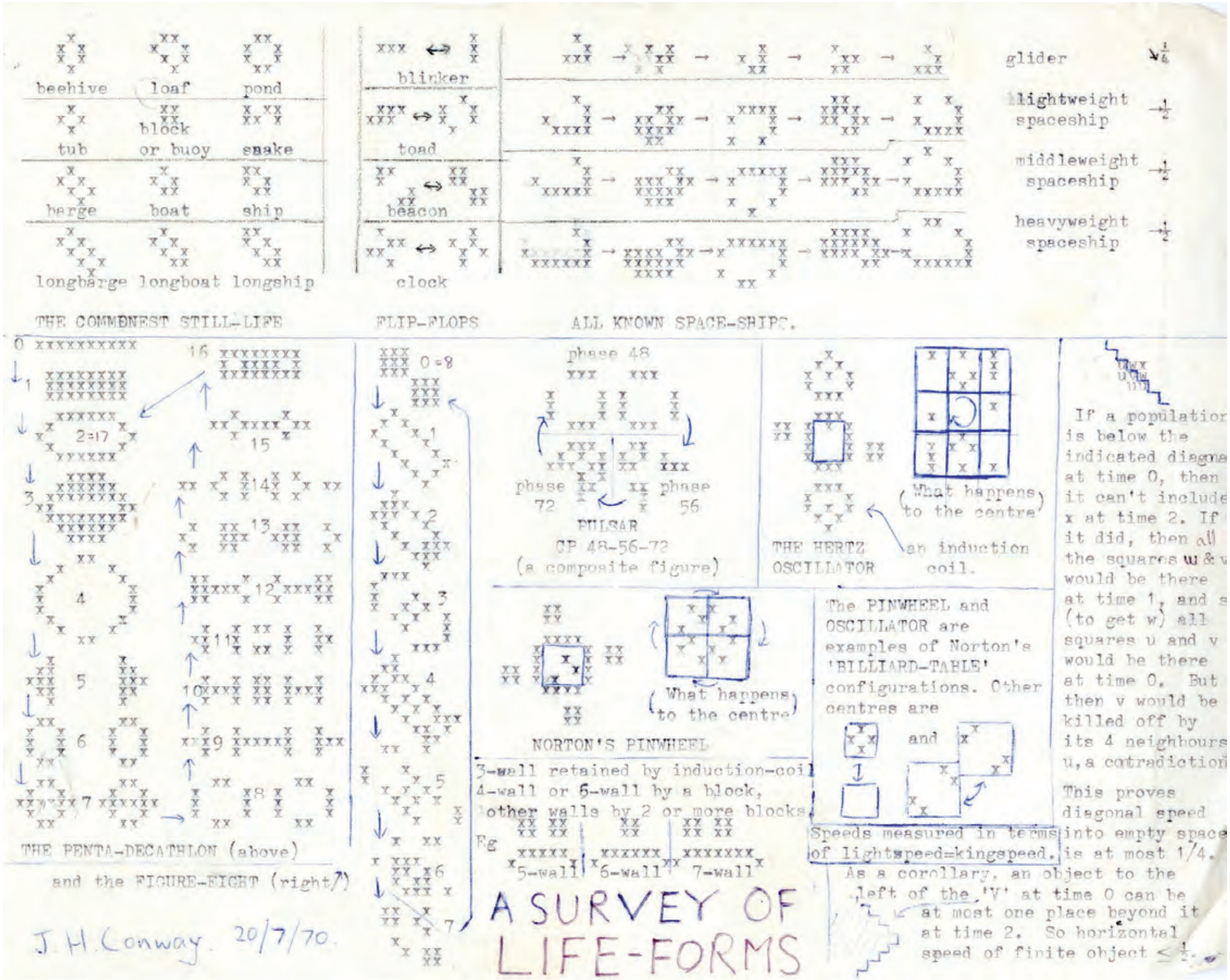
In 2018, there was a much-celebrated discovery of a special kind of spaceship, the first elementary knightship, named Sir Robin. Made of hundreds of cells, it moves two cells forward and one sideways every six generations. It was discovered by Adam P. Goucher, a British algorithmist, building on an earlier partial find by Tomas Rokicki, a developer of Golly, a program for exploring the distant future of large Life patterns.

And the hunting party continues. In September, Pavel Grankovskiy, of Russia, discovered the Speed Demonoid spaceship. In December, John Winston Garth, of Alabama, discovered the Doo-dah spaceship. Both are contenders for pattern of the year, in what has been a good year for new Life discoveries.

Life ultimately became way too popular for Dr. Conway's liking. Whenever the subject came up, he would bellow, "I hate Life!" But in his final years he learned to love Life again. He narrated a documentary, with the working title "Thoughts on Life," by the Brooklyn-based mathematician and filmmaker Will Cavendish, exploring the deterministic Game of Life versus the Free Will Theorem, a result Dr. Conway proved with his Princeton colleague Simon Kochen.

"I used to go around saying, 'I hate Life,'" Dr. Conway says in the film. "But then I was giving a lecture somewhere, and I was introduced as 'John Conway, Creator of Life.' And I thought, 'Oh, that's quite a nice way to be known.' So I stopped saying 'I hate Life' after that."

Recently, some of Life's most steadfast friends reflected upon its influence and lessons over half a century.



The Martin Gardner Literary Interests/Special Collections, Stanford University Libraries

Bill Gosper

— Mathematician and programmer, Stanford, Calif.

Life is the world's most wholesome computer game! True, it used to be dangerously addicting to some of us, but not so much now that nearly all of the theoretically possible gun and oscillator periods have been found. It took 40 years to find the coveted Snark, a stable pattern that reflects gliders 90 degrees.

But there are still open questions: for example, what spaceship vector velocities are possible, or what constructions are possible with glider collisions. A startling recent theorem states that any construction, no matter how large, can be accomplished with a reverse caber-tosser built from a certain fixed number of gliders — that number was 32, but as of September it is now down to 17.

These days it has become harder and harder for an amateur to find a newsworthy pattern without fancy software and hardware. Perhaps Life can remain a gateway drug, luring newcomers into the effectively inexhaustible universe of different Lifelike rules.

Brian Eno

— Musician, London

I first encountered Life at the Exploratorium in San Francisco in 1978. I was hooked immediately by the thing that has always hooked me — watching complexity arise out of simplicity.

Life ought to be very predictable and boring; after all, there are just three simple rules that determine the position of some dots on a grid. That really doesn't sound very interesting until you start tweaking those rules and watching what changes.

Life shows you two things. The first is sensitivity to initial conditions. A tiny change in the rules can produce a huge difference in the output, ranging from complete destruction (no dots) through stasis (a frozen pattern) to patterns that keep changing as they unfold.

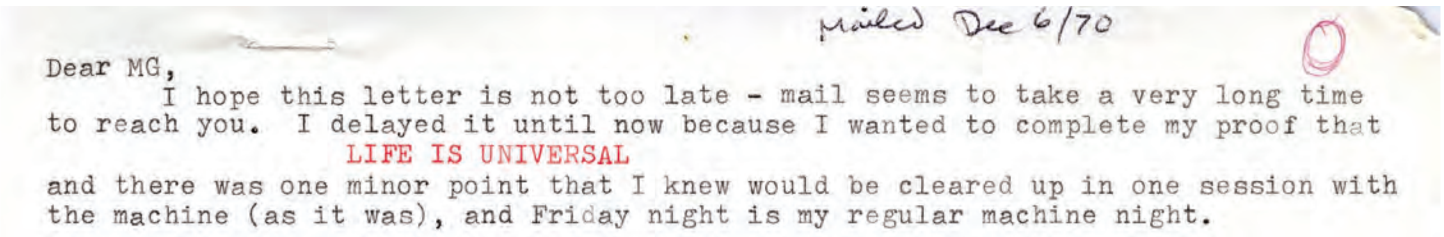
The second thing Life shows us is something that Darwin hit upon when he was looking at Life, the organic version. Complexity arises from simplicity! That is such a revelation; we are used to the idea that anything complex must arise out of something more complex. Human brains design airplanes, not the other way around. Life shows us complex virtual "organisms" arising out of the interaction of a few simple rules — so goodbye "Intelligent Design."

Melanie Mitchell

— Professor of complexity, Santa Fe Institute

Given that Conway's proof that the Game of Life can be made to simulate a Universal Computer — that is, it could be "programmed" to carry out any computation that a traditional computer can do — the extremely simple rules can give rise to the most complex and most unpredictable behavior possible. This means that there are certain properties of the Game of Life that can never be predicted, even in principle!

In this moment in time, it's important to emphasize that inherent unpredictability — so well illustrated in even the simple Game of Life — is a feature of life in the real world as well as in the Game of Life. We have to figure out ways to flourish in spite of the inherent unpredictability and uncertainty we constantly live with. As the mathematician John Allen Paulos so eloquently said, "Uncertainty is the only certainty there is, and knowing how to live with insecurity is the only security." This is, I think, Life's most important lesson.



Mailed Dec 6/70

Dear MG,
I hope this letter is not too late - mail seems to take a very long time to reach you. I delayed it until now because I wanted to complete my proof that
LIFE IS UNIVERSAL
and there was one minor point that I knew would be cleared up in one session with the machine (as it was), and Friday night is my regular machine night.

The Martin Gardner Literary Interests/Special Collections, Stanford University Libraries

Daniel Dennett

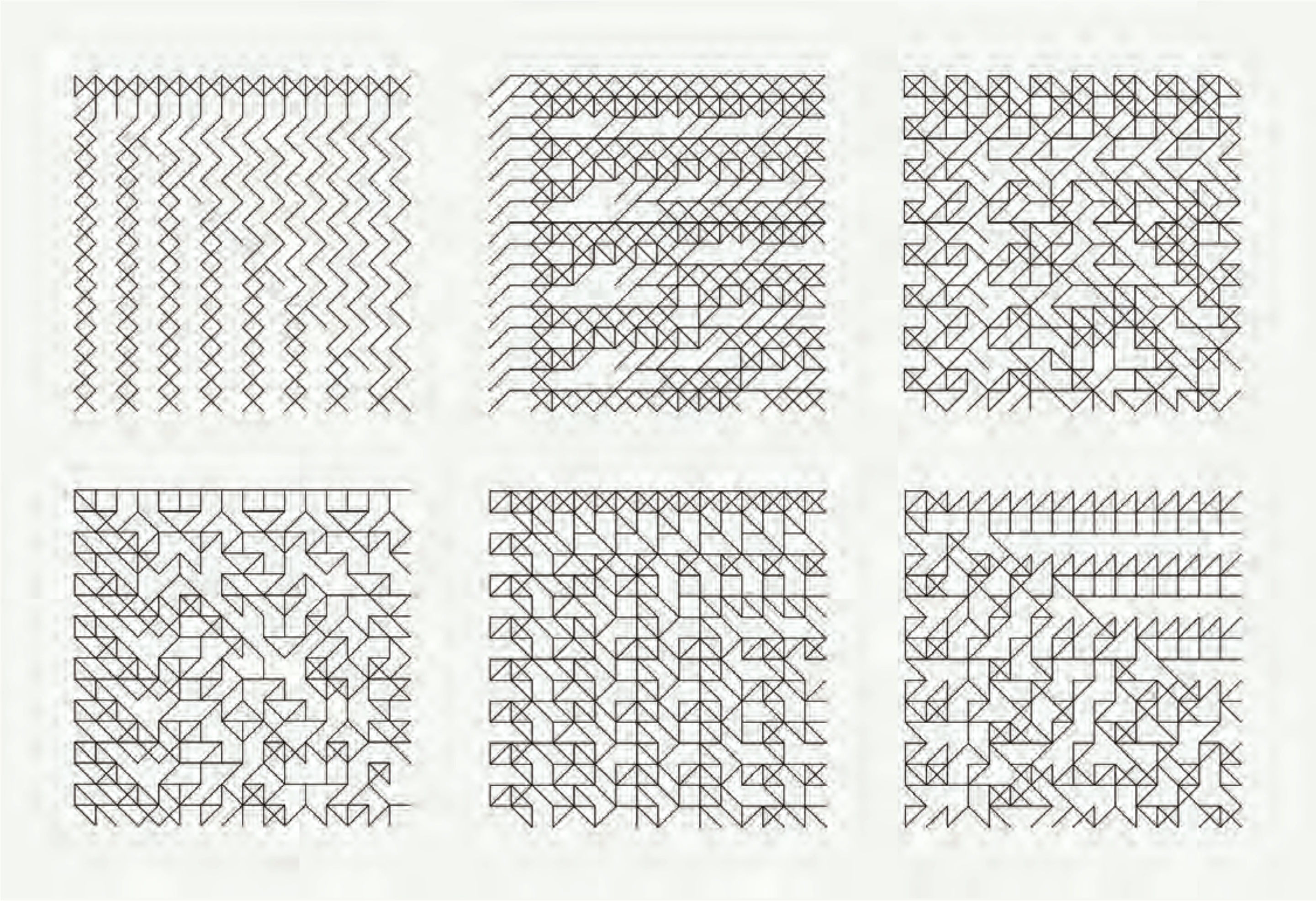
— Professor of philosophy, Tufts University

I use the Game of Life to make vivid for my students the ideas of determinism, higher-order patterns and information. One of its great features is that nothing is hidden; there are no black boxes in Life, so you know from the outset that anything that you can get to happen in the Life world is completely unmysterious and explicable in terms of a very large number of simple steps by small items. No psionic fields, no morphic resonances, no élan vital, no dualism. It's all right there. And the fact that it can still support complex adaptively appropriate structures that do things is also important.

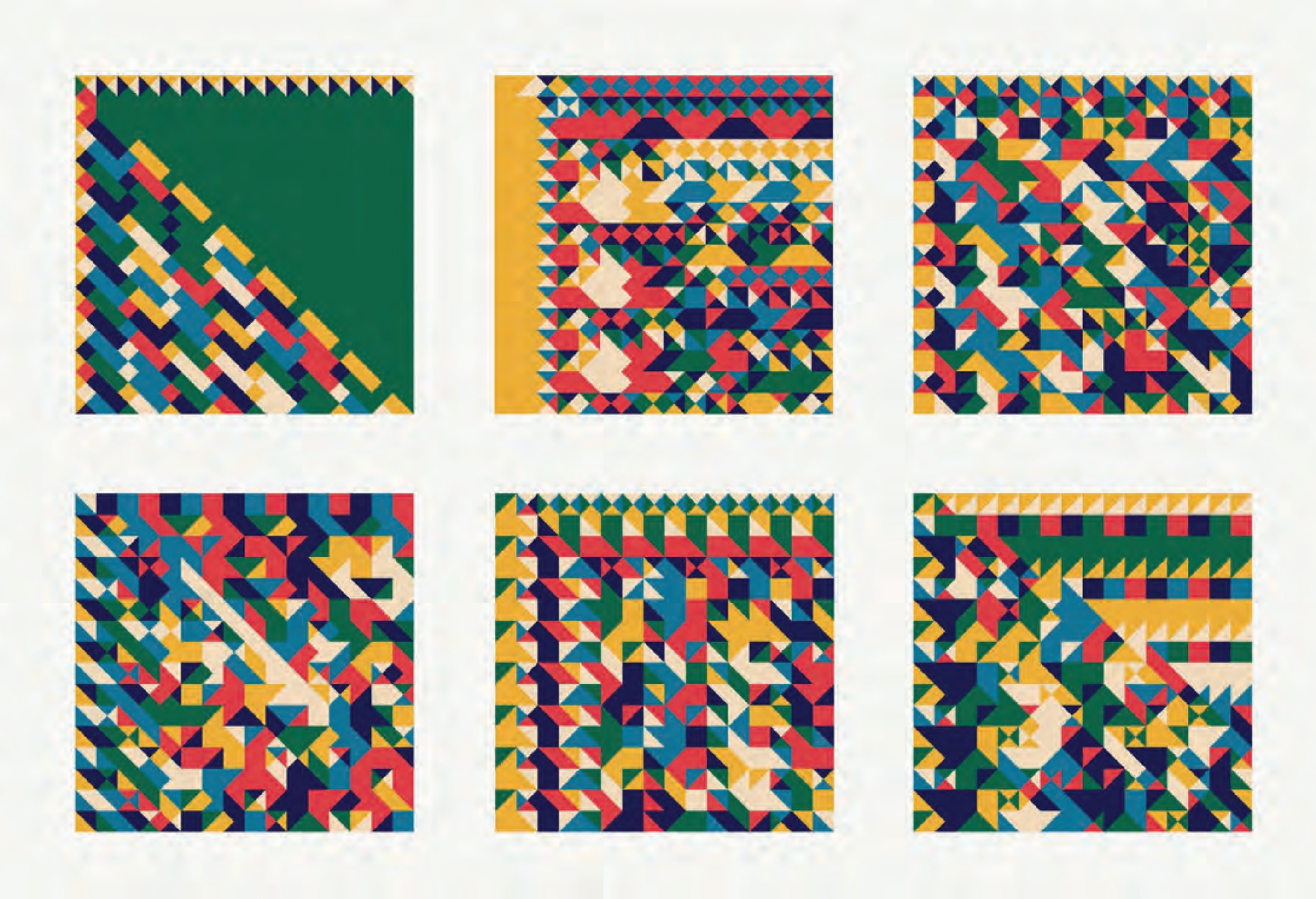
In Thomas Pynchon's novel "Gravity's Rainbow," a character says, "But you had taken on a greater and more harmful illusion. The illusion of control. That A could do B. But that was false. Completely. No one can do. Things only happen."

This is compelling but wrong, and Life is a great way of showing this.

In Life, we might say, things only happen at the pixel level; nothing controls anything, nothing does anything. But that doesn't mean that there is no such thing as action, as control; it means that these are higher-level phenomena composed (entirely, with no magic) from things that only happen.



The Norwegian artist Kjetil Golid's [Crosshatch Automata] are part of an exhibition, "The Game of Life, Emergence in Generative Art," at the [Kate Vass Gallery] in Zurich. The line patterns (above) represent cellular automata in which cells are defined by lines in four different orientations. The colors of a given cell are determined by its line dividers and adjacent colors (below, the result). Kjetil Golid



Kjetil Golid

Susan Stepney

— Professor of computer science, University of York, England

In the Artificial Life community, Life is a foundational piece of work. It sits in the background, influencing the way people think of life "in silico."

Life probably maintains its interest for two reasons. One is that the whole field of cellular automata is very important, because computationally it can be used to model so many different things — for example, physical systems from fluid dynamics to coupled magnetic spins to chemical reaction-diffusion systems.

The other reason is that it's just cool and pretty and great to look at. When you speed it up, it flows and boils and bubbles; it actually comes to look alive.

I did some work with students looking at Life on a Penrose tiling grid, rather than the square grid. I wanted to know whether it was the rules or the grid that was the important thing. We found some interesting oscillating patterns and snakelike patterns. Basically, what we showed is that there is something in those rules; the rules are producing the interesting dynamics. Penrose Life still generates interesting behaviors, even in a different environment.

A Penrose Life oscillator known as "The Bat." Animation by Susan Stepney

Stephen Wolfram

— Scientist and C.E.O., Wolfram Research

I've wondered for decades what one could learn from all that Life hacking. I recently realized it's a great place to try to develop "meta-engineering" — to see if there are general principles that govern the advance of engineering and help us predict the overall future trajectory of technology. One can look at microprocessors or airplanes, but they involve all sorts of details of physics and materials. In Life there's 50 years of "engineering development," just applied to configurations of bits. It's the purest example I know of the dynamics of collective human innovation.

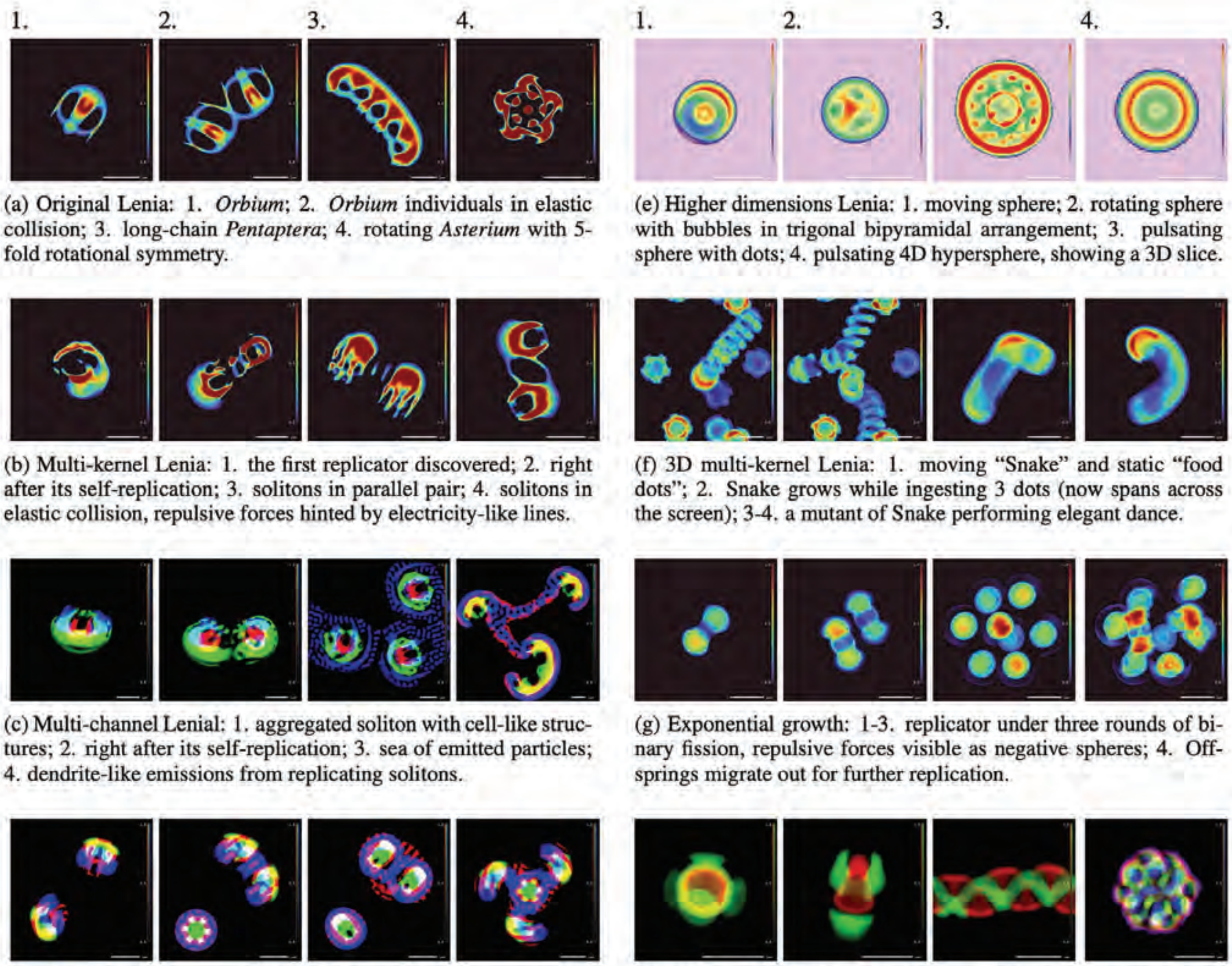
Bert Chan

— Artificial-life researcher and creator of the continuous cellular automaton "Lenia," Hong Kong

Although the Game of Life is not the proudest invention of Conway, according to himself, it did have a big impact on beginner programmers, like me in the 90s, giving them a sense of wonder and a kind of confidence that some easy-to-code math models can produce complex and beautiful results. It's like a starter kit for future software engineers and hackers, together with Mandelbrot Set, Lorenz Attractor, et cetera.

Life enthusiasts have discovered or engineered many wonderful patterns inside Life. Some of the most amazing ones are a digital clock, a simulation of Life inside Life, and self-replicators. The engineering is so ingenious and delicate that a single mistake of misplacing one cell among perhaps a million cells will make the whole machine fail. On the other hand, when I was investigating Lenia — a continuous extension of Life — I found that its patterns are fundamentally different from those in Life. Lenia patterns are fuzzy, thus not easy for engineering (they are mostly evolved instead), but are harder to destroy. Although having the same root, Life and Lenia have nearly opposite nature: designed versus organic, precise versus adaptive, fragile versus resilient.

These are interesting findings in research, but if we think about our everyday life, about corporations and governments, the cultural and technical infrastructures humans built for thousands of years, they are not unlike the incredible machines that are engineered in Life. In normal times, they are stable and we can keep building stuff one component upon another, but in harder times like this pandemic or a new Cold War, we need something that is more resilient and can prepare for the unpreparable. That would need changes in our "rules of life," which we take for granted.



(a) Original Lenia: 1. *Orbium*; 2. *Orbium* individuals in elastic collision; 3. long-chain *Pentaptera*; 4. rotating *Asterium* with 5-fold rotational symmetry.

(e) Higher dimensions Lenia: 1. moving sphere; 2. rotating sphere with bubbles in trigonal bipyramidal arrangement; 3. pulsating sphere with dots; 4. pulsating 4D hypersphere, showing a 3D slice.

(b) Multi-kernel Lenia: 1. the first replicator discovered; 2. right after its self-replication; 3. solitons in parallel pair; 4. solitons in elastic collision, repulsive forces hinted by electricity-like lines.

(f) 3D multi-kernel Lenia: 1. moving "Snake" and static "food dots"; 2. Snake grows while ingesting 3 dots (now spans across the screen); 3-4. a mutant of Snake performing elegant dance.

(c) Multi-channel Lenial: 1. aggregated soliton with cell-like structures; 2. right after its self-replication; 3. sea of emitted particles; 4. dendrite-like emissions from replicating solitons.

(g) Exponential growth: 1-3. replicator under three rounds of binary fission, repulsive forces visible as negative spheres; 4. Offsprings migrate out for further replication.

(d) "Aquarium" phenotypes: 1-3. (left to right) gyrating, slightly oblique; stationary, parallel pair; slow-moving, parallel slow-moving; 4. a few solitons in a stable, dynamic formation.

(h) 3D multi-channel Lenia: 1. tetrapod; 2. moving soliton with red nucleus and green pseudopods; 3. double helix pattern; 4. rainbow ball.

Bert Chan

Rudy Rucker

— Mathematician and author of "Ware Tetralogy," Los Gatos, Calif.

When Life started out, we didn't yet have the notion of mathematical chaos. The unfolding of the successive generations of a Game of Life board is completely deterministic. If you start with the same setup, you always get the same outcomes. The odd thing is that, even though the results of a given game of Life start-position are predetermined, there is no easy shortcut to predict these outcomes. You just have to run the damn thing through all its steps.

That's what chaos is about. The Game of Life, or a kinky dynamical system like a pair of pendulums, or a candle flame, or an ocean wave, or the growth of a plant — they aren't readily predictable. But they are not random. They do obey laws, and there are certain kinds of patterns — chaotic attractors — that they tend to produce. But again, unpredictable is not random. An important and subtle distinction which changed my whole view of the world.

William Poundstone

— Author of "The Recursive Universe: Cosmic Complexity and the Limits of Scientific Knowledge," Los Angeles, Calif.

The Game of Life's pulsing, pyrotechnic constellations are classic examples of emergent phenomena, introduced decades before that adjective became a buzzword.

Fifty years later, the misfortunes of 2020 are the stuff of memes. The biggest challenges facing us today are emergent: viruses leaping from species to species; the abrupt onset of wildfires and tropical storms as a consequence of a small rise in temperature; economies in which billions of free transactions lead to staggering concentrations of wealth; an internet that becomes more fraught with hazard each year. Looming behind it all is our collective vision of an artificial intelligence-fueled future that is certain to come with surprises, not all of them pleasant.

The name Conway chose — the Game of Life — frames his invention as a metaphor. But I'm not sure that even he anticipated how relevant Life would become, and that in 50 years we'd all be playing an emergent game of life and death.

Dr. Conway in his Princeton office in 1993. Dith Pran/The New York Times

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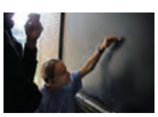
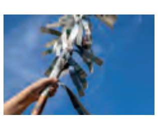
Games, Algorithms and More

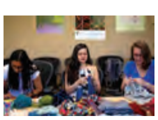


Travels With John Conway, in 258 Septillion Dimensions
May 16, 2020

John Horton Conway, a 'Magical Genius' in Math, Dies at 82
April 15, 2020



Use Your Newspaper to Make a Flibber (A What?)
Oct. 3, 2020



'Knitting Is Coding' and Yarn Is Programmable in This Physics Lab
May 17, 2019

The Yoda of Silicon Valley

Dec. 17, 2018

A version of this article appears in print on Dec. 29, 2020, Section D, Page 1 of the New York edition with the headline: Life, In All Its Glory. Order Reprints | Today's Paper | Subscribe

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The Curious World of Mathematics

- Earlier this year, mathematicians discovered a unique shape: an "einstein." Now do-it-yourselfers have found ingenious ways to put it to use.
- An online math community faced a problem-solving dilemma when it was asked a simple question: How can you chop a square into four similar rectangles?
- What is the sum of an infinite series of natural numbers? The answer may be smaller than you think.
- A Texas oil heir was fascinated with one of math's greatest enigmas: Fermat's theorem. His private support may have been a critical factor in its solution.

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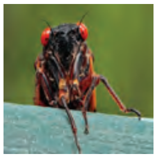

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The Eclipse That Ended a War and Shook the Gods Forever

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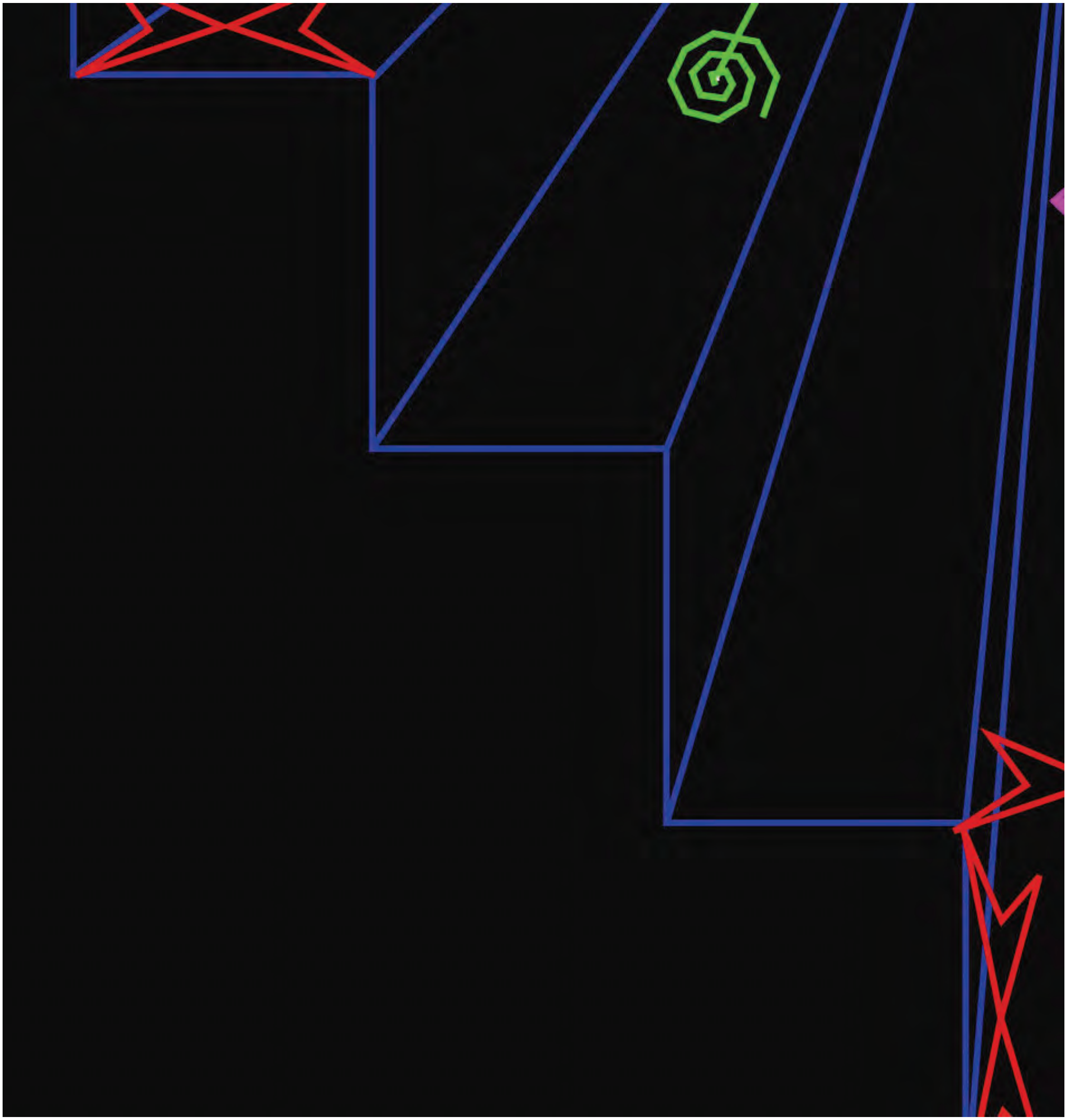
When Video Games Came to the Museum | Magazine | MoMA

Paola Antonelli



A decade ago, MoMA acquired 14 video games—andkicked off a new era for the collection. Today thereare 36, and many are in the exhibition *Never Alone*.

[Paola Antonelli, Paul Galloway]

Nov 3, 2022

This article, presented on the occasion of the exhibition *Never Alone: Video Games and Other Interactive Design*, reprints a pair of posts that originally appeared on Inside/Out: A MoMA/MoMA PS1 Blog on November 29, 2012, and June 28, 2013, by Paola Antonelli and Paul Galloway, respectively.

Video Games: 14 in the Collection, for Starters

November 29, 2012

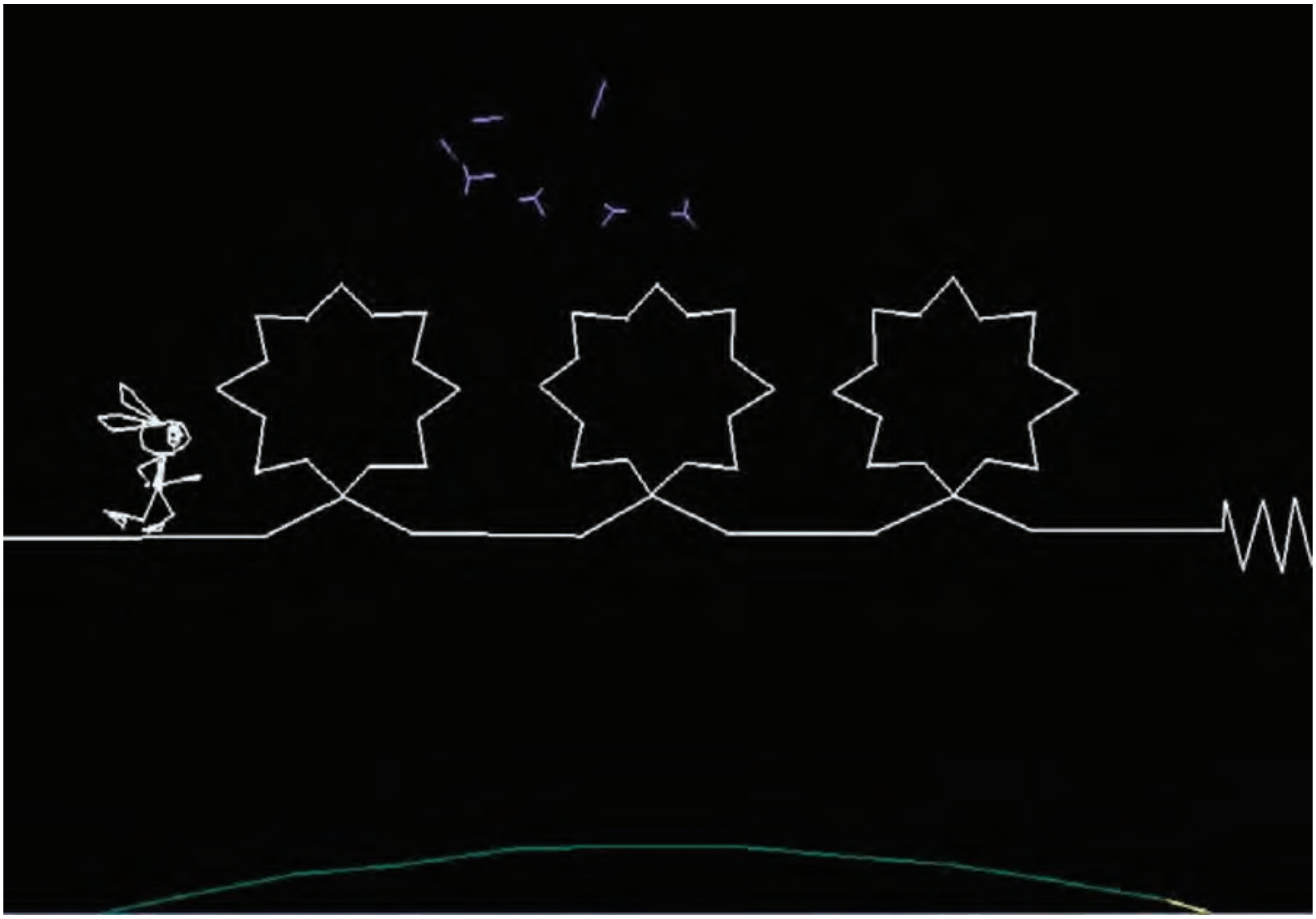
Alexey Pajitnov. *Tetris*. 1984

Adam Saltsman, Daniel Baranowsky. *Canabalt*. 2009

Over the next few years, we would like to complete this initial selection with *Spacewar!* (1962), an assortment of games for the Magnavox

Odyssey console (1972), *Pong* (1972), *Snake* (originally designed in the 1970s; the Nokia phone version dates from 1997), *Space Invaders* (1978), *Asteroids* (1979), *Zork* (1979), *Tempest* (1981), *Donkey Kong* (1981), *Yars' Revenge* (1982), *M.U.L.E.* (1983), *Core War* (1984), *Marble Madness* (1984), *Super Mario Bros.* (1985), *The Legend of Zelda* (1986), *NetHack* (1987), *Street Fighter II* (1991), *Chrono Trigger* (1995), *Super Mario 64* (1996), *Grim Fandango* (1998), *Animal Crossing* (2001), and *Minecraft* (2011).

Valve. *Portal*. 2005–07



Masaya Matsuura. *Vib-Ribbon*. 1997–99

As with all other design objects in MoMA's collection, from posters to chairs to cars to fonts, curators seek a combination of historical and cultural relevance, aesthetic expression, functional and structural soundness, innovative approaches to technology and behavior, and a successful synthesis of materials and techniques in achieving the goal set by the initial program. This is as true for a stool or a helicopter as it is for an interface or a video game, in which the programming language takes the place of the wood or plastics, and the quality of the interaction translates in the digital world what the synthesis of form and function represent in the physical one. Because of the tight filter we apply to any category of objects in MoMA's collection, our selection does not include some immensely popular video games that might have seemed like no-brainers to video game historians. Among the central interaction design traits that we have privileged are:

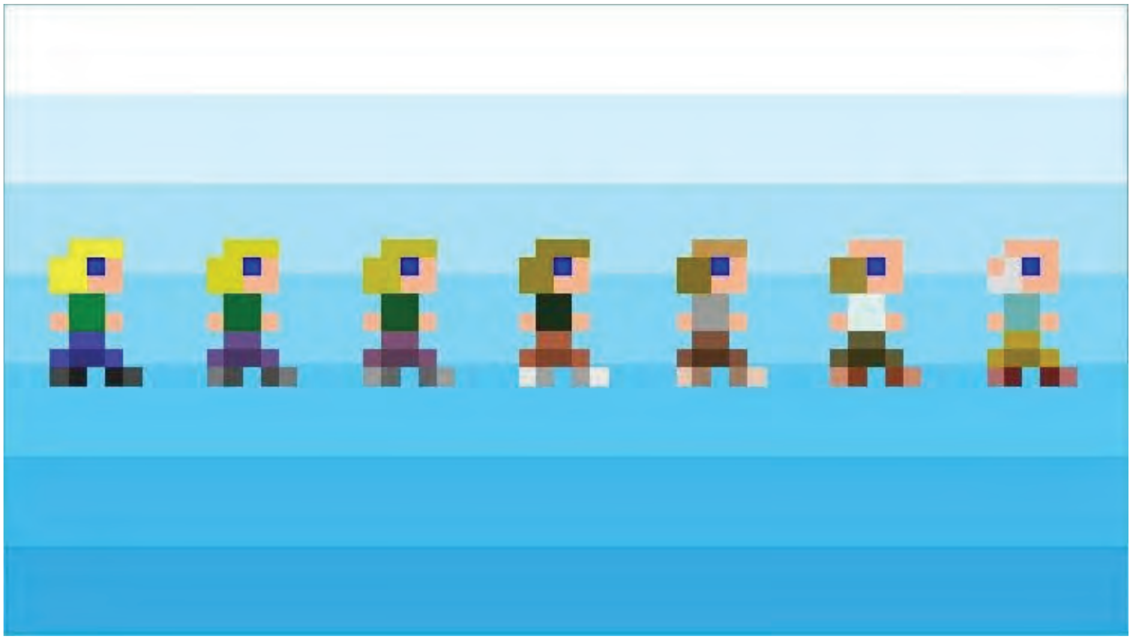
Will Wright. *SimCity 2000*. 1993

Aesthetics
Visual intention is an important consideration, especially when it comes to the selection of design for an art museum collection. As in other forms of design, formal elegance has different manifestations that vary according to the technology available. The dry and pixilated grace of early games like *M.U.L.E.* and *Tempest* can thus be compared to the fluid seamlessness of *flOw* and *Vib-Ribbon*. Just like in the real world, particularly inventive and innovative designers have excelled at using technology's limitations to enhance a game's identity—for instance in *Yars' Revenge*.

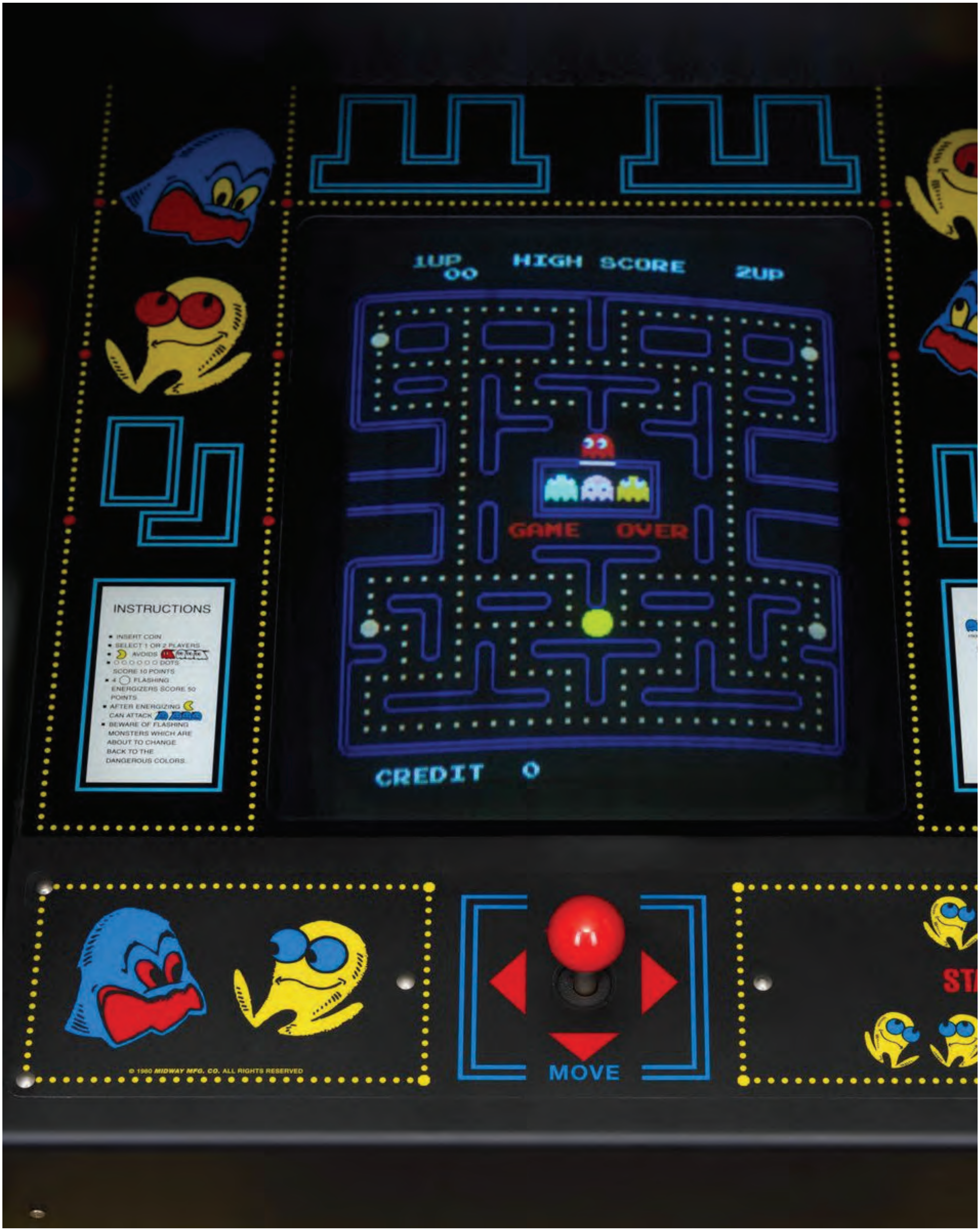
Jenova (Xinghan) Chen, Nick Clark. *flOw*. 2007

Space
The space in which the game exists and evolves—built with code rather than brick and mortar—is an architecture that is planned, designed, and constructed according to a precise program, sometimes pushing technology to its limits in order to create brand new degrees of expressive and spatial freedom. As in reality, this space can be occupied individually or in groups. Unlike physical constructs, however, video games can defy spatial logic and gravity, and provide brand new experiences like teleportation and ubiquity.

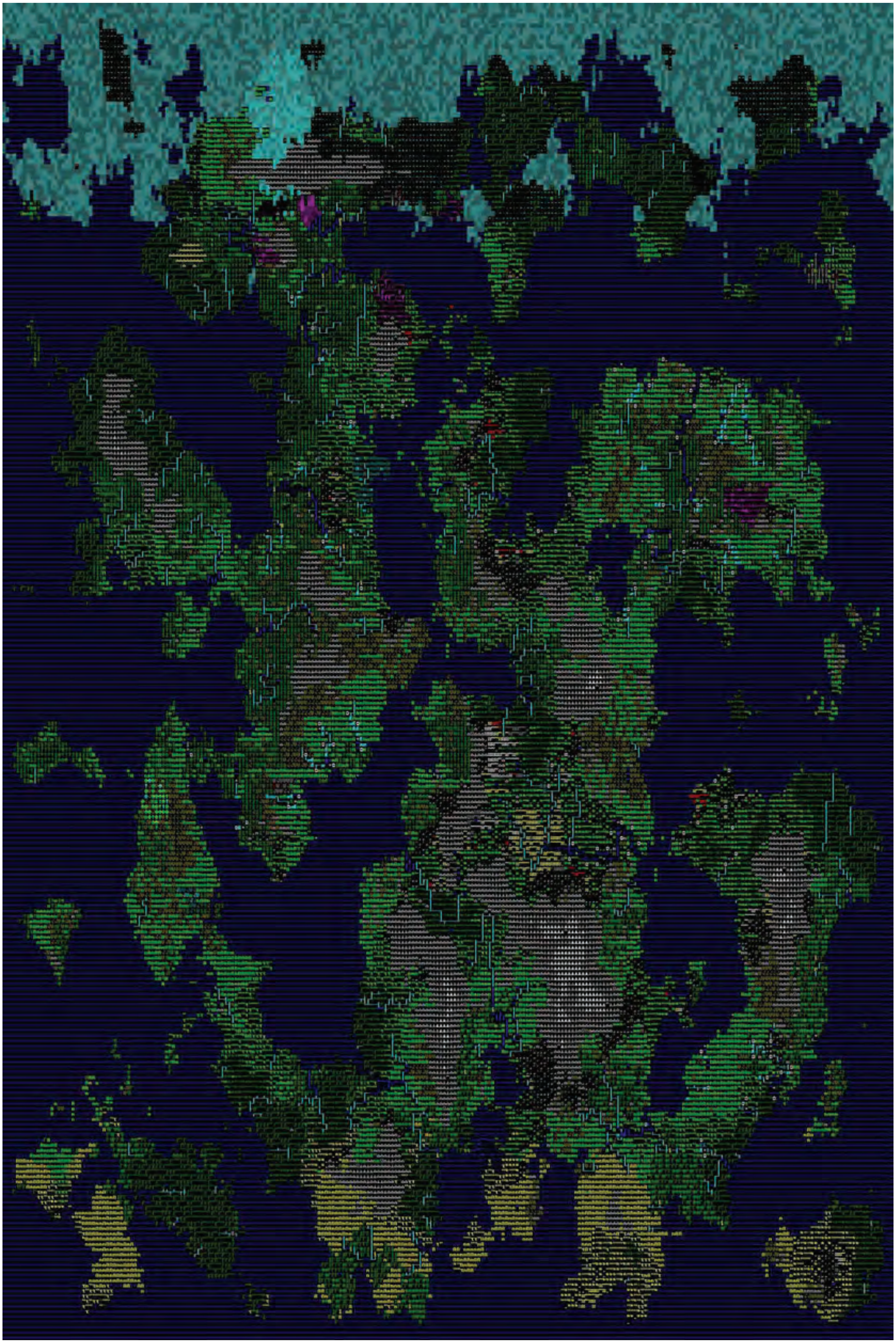
Time
How long is the experience? Is it a quick five minutes, as in *Passage*? Or will it entail several painstaking years of bliss, as in *Dwarf Fortress*? And whose time is it anyway, the real world's or the game's own, as in *Animal Crossing*? Interaction design is quintessentially dynamic, and the way in which the dimension of time is expressed and incorporated into the game—through linear or multi-level progressions, burning time crushing obstacles and seeking rewards and goals, or simply wasting it—is a crucial design choice.



Jason Rohrer. *Passage*. 2007



Toru Iwatani. *Pac-Man*. 1980



Tarn Adams, Zach Adams. *Dwarf Fortress*. 2006

In other cases, when the game is too complex or too time consuming to be experienced as an interactive display in the galleries, we will create a video akin to a demo, in which the concept and characters of the game are laid out.

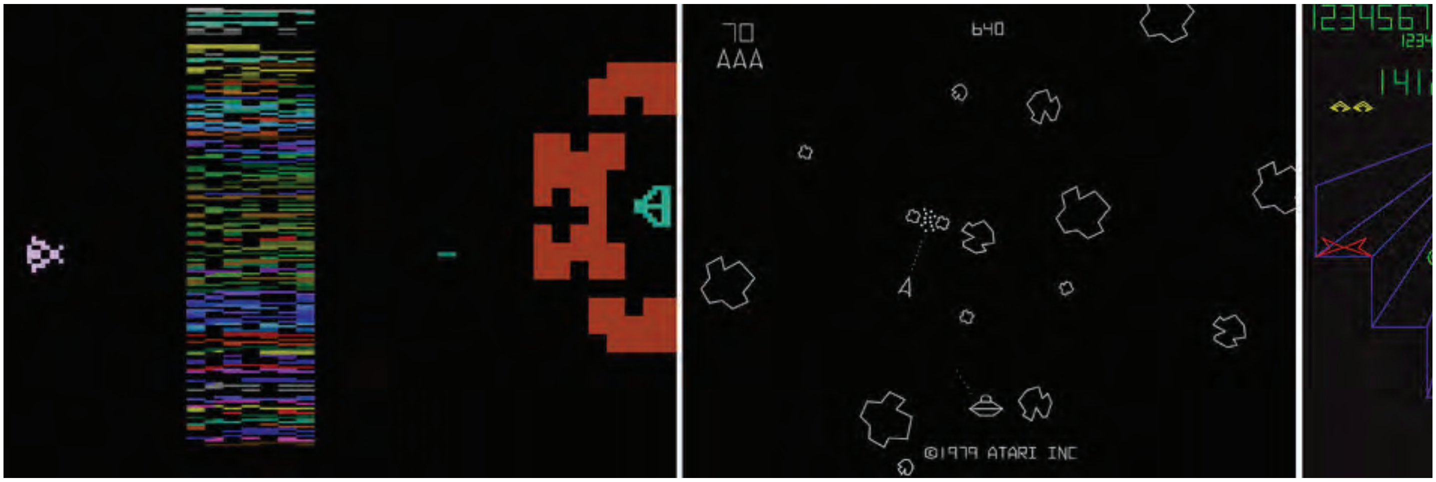
Finally, some of the games we have acquired (for instance, *Dwarf Fortress* and *EVE Online*) take years and millions of people to manifest fully. To convey their experience, we will work with players and designers to create guided tours of these alternate worlds, so the visitor can begin to appreciate the extent and possibilities of the complex gameplay.

Allan Alcorn. *Pong*. 1972

Video Games: Seven More Building Blocks in MoMA's Collection

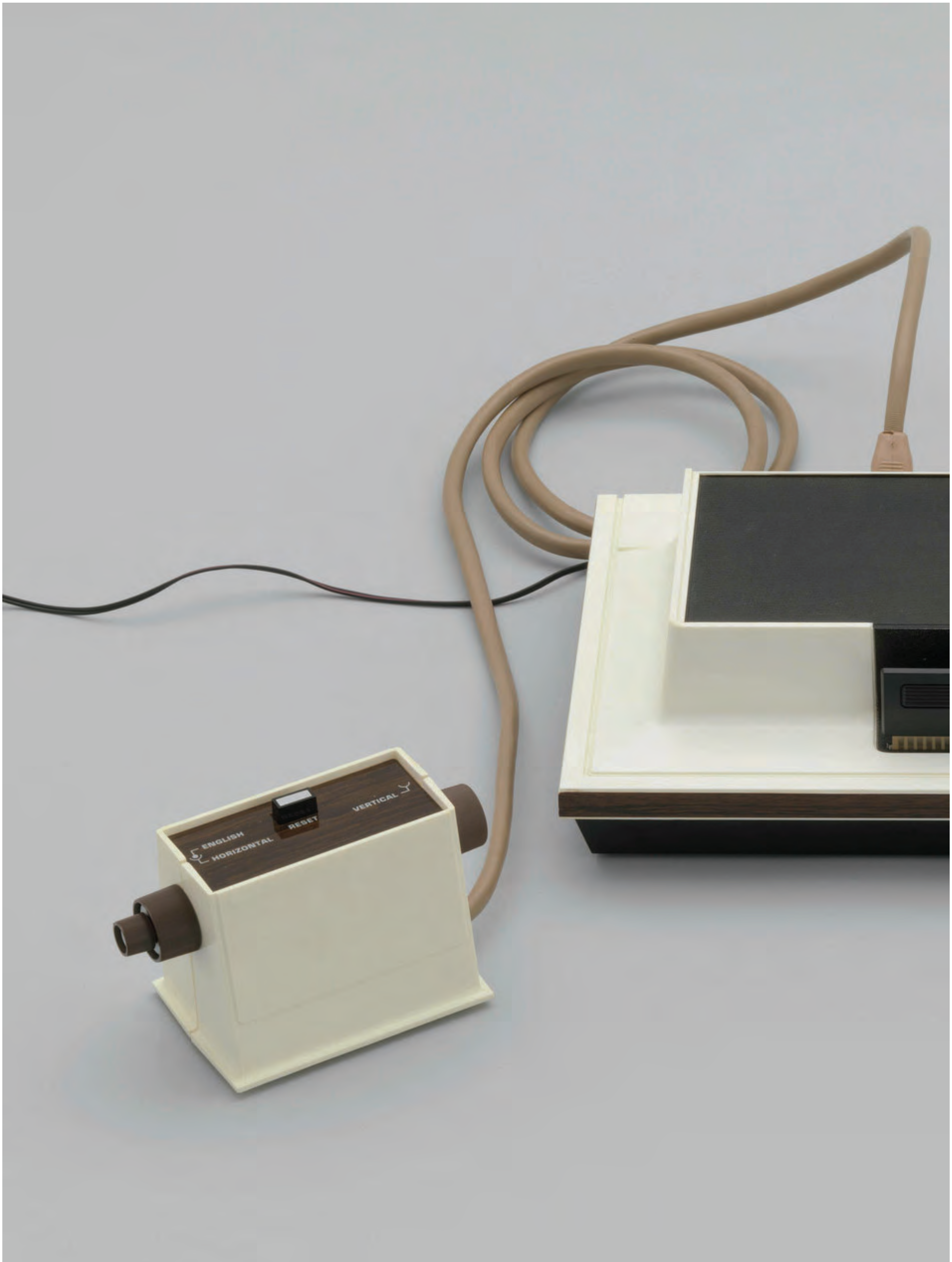
June 28, 2013

Quite a lot has happened since we announced the first 14 video games to enter the MoMA collection, seven months ago. MoMA Architecture and Design curator Paola Antonelli charmed Stephen Colbert, the exhibition *Applied Design* (featuring the games) opened to the public, and a heady debate raged regarding MoMA's move into this field. (For more on this, watch Paola's recent TED talk.) While all this was occurring, we continued the work of acquiring more games from our wish list.



From left: Howard Scott Warshaw. *Yars' Revenge*. 1982; George "Ed" Logg, Lyle Rains. *Asteroids*. 1979; Dave Theurer. *Tempest*. 1981

Today, we are thrilled to announce the addition of one gaming console and six more video games to our collection. These include works from the early pioneers Atari, Taito, and Ralph Baer, and from the comparatively young Mojang. The new additions are the Magnavox Odyssey (1972); *Pong* (1972); *Space Invaders* (1978); *Asteroids* (1979); *Tempest* (1981); *Yars' Revenge* (1982); and *Minecraft* (2011).


ENGLISH
HORIZONTAL
RESET
VERTICAL

Ralph Baer. Magnavox Odyssey. 1972

Ralph Baer's Magnavox Odyssey, the first home video game system and a masterpiece of engineering and industrial design, introduced electronic games to the American public. In the same year, a young and ambitious Nolan Bushnell founded Atari (where, by the way, an equally young and at least equally ambitious man named Steve Jobs first found employment). Atari rapidly became the most famous video game company in the world, and in an amazingly fertile period produced one seminal work after another. Concurrently, the already rich arcade culture of Japan was turned on its head with the release of Taito's *Space Invaders*, a game that so captivated the Japanese public it led to a temporary nationwide shortage of 100-yen coins. When *Space Invaders* finally made it to the US, it conquered the arcade industry. The last work on our list is Mojang's *Minecraft*, a fascinating game that combines multiple genres into one sprawling, unpredictable, and utterly addictive masterpiece.

Markus "Notch" Persson. *Minecraft*. 2011

It's hard to overstate the importance of Ralph Baer's place in the birth of the industry, as well as the significant roles Atari, Taito, and Mojang still play. The work of the designers of those early games became the building blocks of a new form of creative expression and design language; blocks upon which contemporary designers like Markus "Notch" Persson and his fellows at Mojang are building to make works that push the medium to wildly new, fascinating, and weird places.

In the infancy of this field a small number of visionaries laid the groundwork for where we are now: an industry of tremendous range and creative output. If I have learned anything in this process it's that the early, seemingly simple games remain as vital and compelling today as they were when we played them in the cacophonous arcades or on the living room floors of our youth.

> The team behind the 2012 acquisition stars MoMA Architecture and Design insiders Kate Carmody and Paul Galloway, but in preparing this research we have sought the advice of numerous people. We could not have done it without their contributions, and thank them wholeheartedly for their generosity, enthusiasm, and time. We will distinguish between RL (you know it, Real Life) and ML (MoMA Life). RL: Jamin Warren and Ryan Kuo of Kill Screen magazine; design philosopher and game author extraordinaire

Kevin Slavin; and Chris Romero of the graduate program in museum studies at New York University. ML: Natalia Calvocoressi, Juliet Kinchin, Aidan O'Connor, and Mia Curran in Architecture and Design; in Graphics, Samuel Sherman; in Audio Visual, Aaron Louis, Mike Gibbons, Lucas Gonzalez, Aaron Harrow and Bjorn Quenemoen; in Information Technology, Matias Pacheco, Ryan Correira, and David Garfinkel; in Digital Media, Allegra Burnette, Shannon Darrough, David Hart, John Halderman, Spencer Kiser, and Dan Phiffer; in Conservation, Glenn Wharton and Peter Oleksik; in General Counsel, Henry Lanman; in Drawings, Christian Rattemeyer; at MoMA PS1, Peter Eleey; in Film, Rajendra Roy, Laurence Kardish, and Josh Siegel; in Media and Performance Art, Barbara London; and in Education, Calder Zwicky.

We also extend our great thanks to the game companies and designers who donated these important works to MoMA. Without their brave, forward-thinking participation, this project would not have been possible. A great thank you to Tarn Adams, CCP, Éric Chahi, Cyan Worlds, Electronic Arts, NAMCO BANDAI, NanaOn-Sha, Jason Rohrer, Adam Saltsman, Sony Computer Entertainment, The Tetris Company, thatgamecompany, Valve, and Will Wright.

Never Alone: Video Games and Other Interactive Design, organized by Paola Antonelli, Senior Curator, Paul Galloway, Collection Specialist, and Anna Burckhardt and Amanda Forment, Curatorial Assistants, Department of Architecture and Design, is on view at MoMA September 10, 2022–July 16, 2023.

PLAYING NATURE: ALENDA Y. CHANG ON GAMING'S ROLE IN THE CLIMATE CRISIS

Cover image: A Pacific Northwest-inspired forest biome from Strange Loop Games' Eco (screenshot credit: John Krajewski)

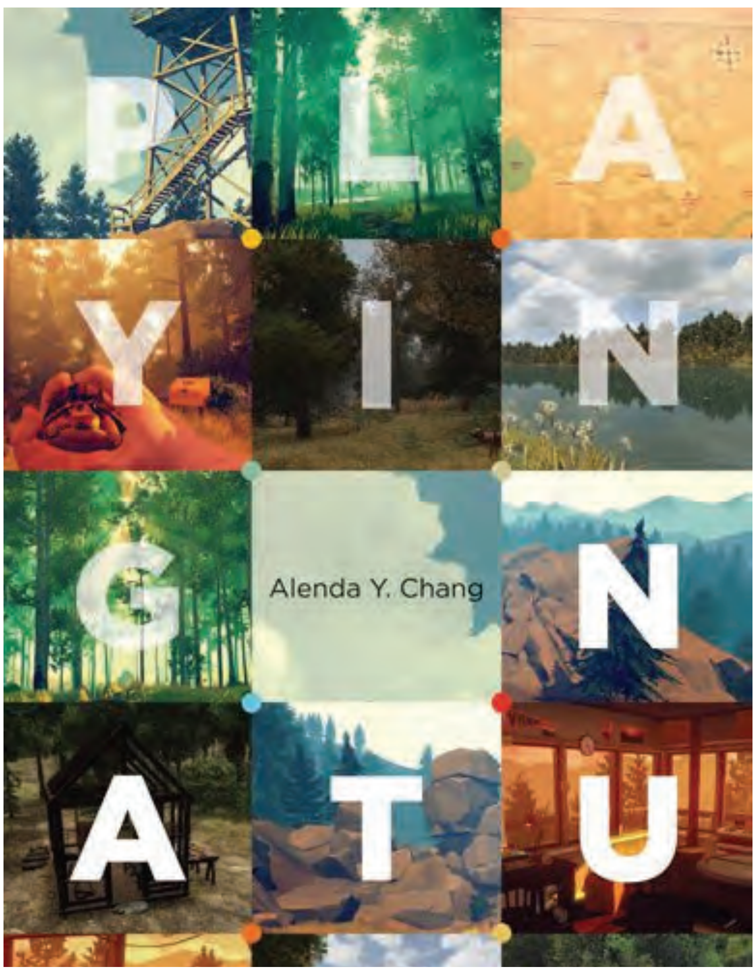
We speak with Alenda Y. Chang, writer, academic and contributor to *Artist Worlds* about the relationship between video games and the natural world and the role that play can have in confronting the climate emergency.

Alenda Y. Chang is the author of *Playing Nature: Ecology in Video Games* (2019), and the cofounder of Wireframe, a digital media studio fostering creative pedagogy, research, and design aligned with issues of social and environmental justice. Chang is also a founding co-editor of the open-access journal, *Media+Environment*. **Kay Watson** is Interim Head of Arts Technologies at the Serpentine.

Kay Watson: I became aware of your writing through the fantastic book *Playing Nature: Ecology in Video Games* (2019) so to begin, for those who are unfamiliar with your research, could you introduce us to your work?

Alenda Chang: In retrospect, I suppose I am one of the intrepid few working in the emerging area of environmental media studies, which to me involves investigating how media and environments shape each other in many ways. Importantly, that shaping doesn't just happen in a standard representational sense, but also entails material and infrastructural considerations. So, to give an example, I'm not just interested in how nature documentaries depict, say, Indonesia or Komodo Dragons; I'm also interested in how streaming that BBC special in full HD glory has its own carbon footprint and how the equipment used to capture footage required metals and 'rare' earth elements from as far away as Bolivia or the Democratic Republic of the Congo. People like me think of 'media' very broadly, too, as more than mass media. As any microbiologist or ecologist will tell you, people and places are media, too. Things pass through us and our environments all the time, and are simultaneously shaped by that passing.

My particular niche in environmental media studies, at least thus far, has been video game environments. This work grew out of my personal attachment to both games and science, as well as a professional recognition that environmental scholars had, until recently, largely neglected interactive media. We had plenty of people writing about the natural world in Jack London or Wordsworth, but next to no one writing about it in games. When I first started writing on this topic, I complained that video games were apt to treat their in-game worlds as either pretty scenery or resource stockpiles, all to the benefit of the player, whose choices and gratifications were held as paramount. But coming at this from the combined standpoints of a long-time player, an amateur naturalist, and student of environmental philosophy and history, I was determined to lay out principles—scientific, artistic, and ethical—with which to create better, meaning more environmentally intelligent, games and game worlds.



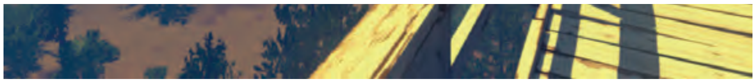
Playing Nature book cover (design credit: University of Minnesota Press, 2019)

KW: What is it about play and video games that offers players or users insight into real world environmental systems and ecological thinking?

AC: In my book, each chapter riffs on a particular term that I think makes for a useful entry point into describing and evaluating game environments. For instance, one of those is the word 'mesocosm', which for scientists describes an experimental design scaled somewhere between natural conditions and the lab. For me, games are similar enterprises, in which certain variables have been established while others have been held constant. Although designers set the initial parameters for these worlds, players bring them to life and constantly test their depth and their boundaries. They operate as both experimenters and experimental subjects. Ecology, meanwhile, is a science heavily influenced by systems thinking, even cybernetics. It makes sense that games, as rule-based systems or computational media, would be readymade channels for ecological modelling.

Playing Nature became, in no small way, this project of teasing out what exactly it is about (primarily digital) games and play that lends itself to noticing, interacting with, and ultimately better understanding our relationship to the natural world, *through* the designed fictions of playable media. I offer some ideas, like the ability to range widely across scales, to play as nonhuman animals and phenomena, or to wreak environmental havoc and face the results, but much remains to be said.

Obviously, games cannot substitute for reality, but for me they are a powerful alternative in a time when most of us are less and less proximate to 'nature' (not to mention pandemic constraints) and nature itself is endangered by human attention. Play itself is also a vital attitude toward our mounting environmental problems. This might seem counterintuitive, but given how paralysing and demoralising typical environmental rhetoric can be, we need play and games perhaps now more than ever—because in play, we have the chance to establish community, tolerance, wonder, and creativity, as well as confront ambiguity and the consequences of our own (or others') actions. Play is hardly a panacea, but it is something we arguably need along with earnestness and righteous anger and grief.



Wyoming's Shoshone national forest from a fire lookout tower in Campo Santo's Firewatch (screenshot credit: Alenda Y. Chang)

KW: As game engine technologies continue to become more sophisticated and enable more hyper-realistic simulations in real time, how important is realism or the quality of rendering games in order to foster relationships between the player and the game world? And therefore, in the context of this conversation, the natural world.

Can you share with us an example of a game or virtual world that best represents some of these ideas in terms of collaboration, cooperation or understanding of ecologies, ecological systems and the non-human world?

AC: I try to write about all sorts of games, both analogue and digital, old and new, in large part because I don't believe sophisticated graphics are necessary to an experience of environmental realism. Of course, I was trained in literature and used to be an English professor, so I suppose I'm more sympathetic than most to the idea that text itself is its own portal to imaginative worlds. I've written about the text game *Adventure*, developed in the 1970s by Will Crowther and Don Woods, and how the game's written descriptions and navigational structure are surprisingly effective at conjuring an underground cave system (no doubt helped by Crowther's spelunking hobby and the game's tie to a real cave system in the United States). That's not to say there isn't a tremendous amount of potential in newer platforms and their affordances. I'm just as wowed as everyone else by millions of "tris" and subsurface light scattering and all that. But to go back to the environmental media approach where I started, I can't help but remain sceptical of these platforms' energy and resource costs and their role in perpetuating unsustainable cycles of technological planned obsolescence.

As for exemplary games, I still find it surprisingly hard to point to titles that do everything well, at least in terms of environmental design. It's much easier to identify games that do certain things well. To give a short list, there's *Firewatch* as a site-specific game (modelled on the Shoshone wilderness); *Beyond Blue* for its honouring of scientific expertise (I recently helped host Mandy Joye, the marine scientist who served as the model for the game's main character and as one of the game's primary science advisors); *Never Alone*, for its honouring of Indigenous expertise; *The Legend of Zelda: Breath of the Wild*, for its admittedly lush open world and dynamic weather modelling; *Eco*, for its audacious simulation of ecological interdependence and collective governance; and finally, even the massively multiplayer *World of Warcraft*, which I used to play, because there's something humbling about a persistent game world that doesn't vanish when you log off or stop subscribing.

KW: I know that you're also working on the development of a game – *Corridors* – could you tell us more about that project and some of the ideas behind it?

AC: *Corridors* is essentially based on the problem of human infrastructure and the way that it has fragmented the natural world and created barriers for the many animal and plant species, and for that matter the natural phenomena like rivers or air currents, that need to navigate them. The most obvious embodiment of this is roadkill, which reaches staggering numbers in terms of animal lives lost *and* property damage. It's actually been available on itch.io, but we never made it past a playable beta, in part because my collaborator and the main coder Intae Hwang finished his doctorate and returned to South Korea. The game is not nearly as much fun to play as it is to write about, or think with. I have a piece in the environmental humanities journal *Resilience* describing the process of putting my theories into practice, and how challenging it was to make my minor obsession with 'wildlife mitigation techniques' (reducing harm to wildlife by installing things like tunnels and overpasses) appealing. In the game's existing five levels, I tried to offer a wider variety of scenarios, where infrastructure could include anything from roads to lights to houses. The trouble is, it's often more fun to flaunt than abide by the level rules. And in the case of wildlife mitigation, I personally believe it's less about what you do than what you choose not to do, and it's hard to hype a game based on inaction rather than action (one reason I'm fond of so-called 'walking simulator' games).

KW: I ask this question as someone from the art world who has reached out to you, but are you finding more interest in your research from outside of academia? In the context of the art world, game engines are now so widely used by artists and institutions for CGI and digital projects, but there is also evidence of wider acceptance of video games as a cultural form by arts organisations (particularly contemporary art) in the last few years, and that has accelerated during the pandemic.

AC: Indeed, one of the best things to come out of publishing my book, beyond the expected gratifications of other scholars reading my work (and tenure!), is exactly what you're describing. I've been surprised and delighted to discover not only that scholars in disciplines outside of my own, like landscape architecture, are finding my work useful, but also that curators, new media artists, scientists, and people working in the game industry are also interested in what I have to say. It has actually been a bit daunting because now I don't just get the usual requests to review for humanities journals and presses; now I get the occasional nod from environmental studies or ecology journals, national science centres, and so on.

I do want to stress how right you are about game engines and digital assets rapidly permeating through all cultural spheres, from landscape design to cinema and television. I loved writing a recent piece about 'digital morphogenesis' and plant modelling by companies like SpeedTree, and may even publish my next book on this topic.

Still from Beyond Blue, an educational underwater diving adventure game developed and published by American studio E-Line Media

KW: In the first volume of *Future Art Ecosystems*, we use the term 'infrastructural plays' as a way of pointing to the often hidden 'back-end' of the art industry that feeds into the public-facing 'front-end' of the art world. Examining the ways that art projects are developed, produced and financialised, and

outputs are distributed, stored and protected that often draw from adjacent industries, such as games. You write about 'infrastructural play', which I think really overlaps with this proposition. Could you tell me a little bit more about this as a concept?

AC: I love that we independently arrived at the same (or a very similar) term, for much the same reasons. For me, infrastructural play is what you do in a game like *Corridors*, or *Phone Story* (which rips the veil away from exploitative mining, manufacturing, marketing, and disposal practices for everyday smartphones). Scholars in critical infrastructure studies like to remind us that infrastructure almost by definition is beneath our notice, and that we don't become aware of it until it breaks. My colleague Lisa Parks, who has written about everything from cell phone antenna trees to satellites, talks about infrastructure as 'the stuff you can kick'. Of course, a good chunk of the developing world (and parts of the developed world, as evidenced by the state of Texas's recent grid failures) don't even have the luxury of taking infrastructure for granted. For me, infrastructural play is directed at bringing these normally hidden relations or dependencies into relief. So it's also a fundamentally ecological project; ecology, after all, strives to situate human beings as one species among many, reliant on a host of biogeochemical factors both within and beyond our control.

Still from Never Alone (Kisima Ingitchuna), the first game developed in collaboration with the Iñupiat, an Alaska Native people.

KW: To end, who or what are you finding most exciting at the intersection of ecology and video games or virtual worlds right now?

AC: Aside from the fantastic work that you're doing at the Serpentine, I can happily report that I see progress being made on multiple fronts: design, scholarship, and industry. More and more game designers are embracing environmental themes and gameplay, and groups like Games for Our Future have been sponsoring and finding growing support for a variety of developer-oriented 'green' game jams, e.g. on climate or clean energy. I'm eagerly awaiting new work from emerging and established scholars on these topics and heartened by what looks like increasing institutional support for environmental humanities/media research (judging anecdotally by the various workshops, talks, and events that I've been invited to be part of). Finally, I'm grateful to have learned about the International Game Developers Association's relatively new climate special interest group which, although volunteer-driven, has been very active and already identified several ways to help game companies develop more climate-conscious games and design practices. These chances to intervene and open up at the levels of production and reception are precisely why I wrote *Playing Nature*.

KW: Thank you Alenda.

Artist Worlds is an ongoing series of commissions and events that support artistic practices that engage with simulated realities, immersive story-telling and virtual world-building and begins with an experimental live multiplayer virtual event focused on the interrelationship between ecology, sustainability and advancing technologies taking place in a revised version of Jakob Kudsk Steensen's 2016 VR work *Primal Tourism,* a virtual island inspired by Bora Bora in French Polynesia.

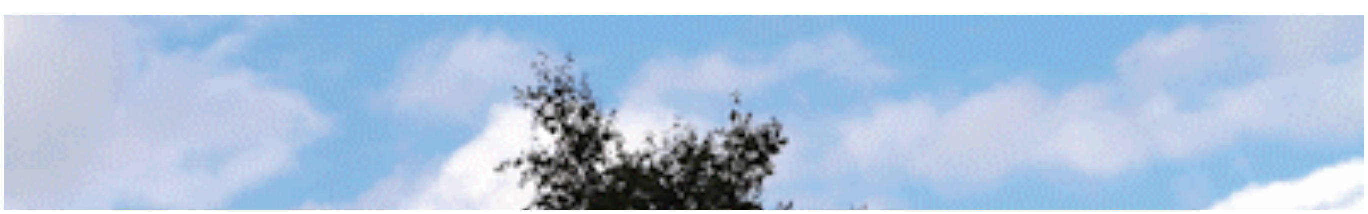
Life Along Tree Time

A MEDITATION ON TREE TIME THROUGH THE TREES OF LJUBLJANA

BY LUA VOLLAARD, OBSERVANT LJUBLJANA SUMMERLAB

#ACT SUMMERLABS

I was tired of speed. I wanted to live to tree time. Those words start off Sumana Roy's newly released book, 'How I became a Tree' [1]. In the work, she shares her admiration for trees; their nonviolent way of being, their ability to cope with loss, their ability to thrive on resources freely available. Mostly, Roy surveys trees' 'disobedience to human time', their callous disregard for the rhythms of job and holidays. In stark contrast to tree time, we live according to a human time that rolls over us like a bulldozer, weighed down by the clocks, timers, and the clicking of seconds that determine concoctions such as salaries and deadlines. In the last week of August, a summer lab organised by performing arts institution Bunker brings together participants from 10 European countries in Ljubljana to exchange on the topic of urban trees; a week-long encounter in tree time.



Life along tree time holds a seductive promise. Although trees, like us, are bound to a circadian rhythm that determines night and day, the very same planetary spins that make up months and seasons, tree time shifts the very scale at which we are to think about time. It is a sort of zooming out: for a tree, a cycle of day and night may be like a single breath. Tree time can be a shift in time scales such as 'phoenix growth'. Phoenix growth is the phenomenon of trees falling in the forest after the completion of their life span, only for new trees to spring up from their fallen trunks. Phoenix growth can be described as a tree walking in slow motion.[2] Each fallen tree from which new saplings spring is a step. Tree time here is the pace of a tree walking: at decades, even centuries, per step. Ursula K. le Guin's writes a story of an oak tree who describes her complicity in the death of an automobile driver, as it moves at too slow a pace to get out of the way of the car in time. [3] When the scale of our own life span meets that of a tree, its outcomes can be violent, alienating, and abrupt experience.

Yet we use tree time as a metaphor to relay the basics of human time. Some of the most popular children's books narrate human life span in parallel to that of a tree or an environment of trees. *The Giving Tree* tells of a character named Boy who has a profound friendship with a tree, providing him with branches to swing from, apples to sell, a house to build from her branches, and even wood for a boat, in all stages of throughout his life. [4] After building the boat, there is nothing but a stump left of the once-regal tree. After each act of giving, it is written, the tree was happy. The book is used in religious circles as proof of the unconditional love of deities, and in just about every other circle, including pedagogical ones, as a textbook example of relationships that are fundamentally unreciprocal, dependent, and exploitative. We know how to extract from trees – but could find ways here to bring something back to the trees that nurture us?

We have a deep, ancestral connection to taking care of trees, and being taken care of by trees. We appreciate them not just for the view they give us from our home or office, but also from a deeper memory of the use of their shade, their cover from the weather, and their fruits. Unlike animals, who we consider to be competition, we are in close relation to plants and trees. We may envy their longer lifespan, yet this longer lifespan also allows us to see our own life as a smaller part of a longer lineage. This is why we call them 'family trees'; we relate the lives of our direct families to those trees who have been silently in the presence of our ancestors. This is also why the community rallies around the protection of trees when they're threatened; the term 'tree hugger', in fact, comes from such an attempt to save trees from being cut down, in 1730s India.[5]

To live without trees could even be to deny yourself of your life's lineage. Another children's book – *The House Held Up By Trees* – spells out the fate of those who don't allow trees in their vicinity. Like *the Giving Tree,* the book follows a person during their entire life span and relates that span to trees around them, tying the time of human life expectancy to the experience of tree time. It tells the story of a man who buys a house to live in with his two young children, where he maintains a meticulous lawn, where no trees can root from. But when the children have left home, and the man desires to sell the house in order to live in the city closer to them, there are no prospective buyers, and the house falls into disrepair. The old man, not being able to keep up with the home's deficits, is eventually lifted up – home and all – by the trees that uproot its foundations. Lawns are a testament to a middle class, continuously laboured life; yet trees are a testament to life according to a set of rules that doesn't centre our experiences, but instead guards histories and legacies.

Cities grow around trees, which become bearers of knowledge and narratives of human presence. In Ljubljana's botanical gardens, I encounter its oldest tree, a 211-year old Cornwall Cherry with many trunks and branches aiming to catch the sunrays across the path. The premises of the institution, buildings, paths, and flowerbeds grew around this tangled being. This tree comes with its own myths. A fox and a bear who encountered the tree in early spring, in bloom. The bear waits by the tree for it to bear fruit. The fox goes on its way looking for other fruit trees. The bear waits and waits for the fruits – but nothing comes. When the fox returns, in autumn, well fed on a variety of things, the bear is not so lucky. The moral of the story is a simple way to relay knowledge about the timing of the harvest: the trees that bloom earliest, bear fruit the latest. The fable about this tree marks its presence throughout the centuries. It's a memory device for us to understand our relationships with the tree – and a fable that has become a founding myth of a creature outlasting us by many generations.

A city is an entity that radically reorganises all life within it according to human scale. This is one of the main takeaways from meeting Maja Simonetti, who has been invited as part of the summer lab. Simonetti has been a landscape designer in Ljubljana for over 30 years, and has an extensive knowledge of the history, inventory, health and management of trees in the city. The trees we're sitting under, she tells us, predate the buildings around us – the paved streets, the small park, and even the cultural institution grew around them. The trees lining the street perpendicular to the plaza, however, stand no such chance. Urban trees have an expected lifespan of ten to fifteen years, after which their exhausted stems give in, prone to disease. They're lucky to survive the first few years. They suffer from the lack of natural water systems, poor quality of soil, winter salting of the streets and bad air quality; but their main issue is the lack of space. As much as 30% of new trees die in their first year. Many new trees are constrained at the root in their pots, and since the tree from its foot to its canopy mirrors its abilities to grow underneath the ground, they do nothing but stay small. Potted, separated trees are dying at high rates, in every city in Europe. Here, the 'wood wide web' is exhaustingly constricted. And although a view on a tree is one of the most highly valued traits of urban life, trees are also considered a danger to built environment itself. Paradoxically, the ability of trees to draw near to housing is now wholly dependent on their solitude as potted beings, lowering their chances of survival. The big trees we know in our cityscapes now could have only been planted when the urban conditions were not adversely affecting their wellbeing. And so the city is a machine, a complex, a network that works to radically restructure the life of trees to approximate that of humans: nearer to the human body in size due to its subterranean strangulation; nearer to the human time of 4-year political cycles than the potentiality of trees to live for hundreds of years. In our current way of living according to tree time in urban environments, we are not allowing the possibilities of knowledge transfer that trees can imbue, which would reflect our own image as part of a longer lineage back to us.

There are a few terms that operate as rhetorical devices which are instrumentalised politically to undercut trees natural movements in the city: 'native' or 'indigenous'; and 'invasive'. These terms need to be problematised in this context. Speaking of plants 'indigenous' to Europe needs to take into account the history of human exchange of seeds and plants that has happened in Europe for hundreds of years. The history of the extraction of plants and seeds as part of the violent colonisation of elsewhere is in fact be one of the histories most indigenous to Europe. Furthermore, the term 'native' can easily be co-opted as a plant analogue to human movement; a group of self-proclaimed 'nativists' in the forest reserve Turnhout who claim the area as their 'ancestral lands', deny the right of 'non-native' northern pine trees to stand on Belgian soil. Claims to plant nativism are a transparent mirror of political ideologies about migration and cultural production, rather than a project of the conditions of common land or ancestry. Similarly, the term 'invasive' casts a judgment on a species' properties rather than humans' faults in their movement and management of the plant for their own purposes. Hogweed, for instance, spread throughout Ljubljana as it was unable to be contained by the botanical gardens, where it was first planted. 'Invasive' as a term essentially shifts the blame, assigning character flaws in tree species for management problems that only exist because they don't fit the planned destination of certain environments, especially urban ones.

Trees are events in nonhuman scale. Any attempt to integrate them into the urban landscape is at the same time a bringing closer to the scale of human life. In that sense, a city to a tree is a bit like what a zoo is to an animal: zoos are environments that drastically prolong the natural lifespan of many kinds of animals held within them. In that, they resemble more of the age-old care humans need by the end of their life. Trees, on the other hand, are radically constricted in their size and life span by the city, tied more closely to the political cycles of urban planning. Human life is a machine that subsumes all other firms of life to more closely resemble its own principles of organisation – culturally, politically, socially. The callousness with which humans approach other forms of life is testified by urban trees. Yet trees resist; they persevere even on salty, cold roads, in restricted, concrete pots.

In 2020, playwright Topher Payne released a remake of *the Giving Tre*e, named *The Tree Who Set Healthy Boundaries*. [6] It starts off with the same pages, but deviates as the Boy comes to the tree to cut their branches to build a house. 'Look', says the tree, 'I was fine with giving you apples, but I am not giving you a *house*… Boy, I love you like family, but I *am not going down like that*.' By the end of the alternative version, the Boy and the tree collaborate, making the best apple pies in town. While the tree becomes one of the strongest and healthiest trees in the forest, she even becomes acquainted to his children and grandchildren. It is a great reworking that foregrounds the resistance of trees. In the morality tale of the twenty-first century, the tree has been reconceptualised to have the kind of agency that would allow it to voice their worries about their relationship to our lineage. At the end of the day, with the constricted scale of urban trees, it is us who are missing out on reflecting on our lives according to the decelerated rhythm of tree time.

Ljubljana's oldest tree stands in front of hostel Dod Lipo – literally, 'under the linden trees'. The city has grown around this being here. They are now a lone linden, a new tree shooting from the hollow core where their rings used to be, at 400 years old. When this tree was 12, Galilei was sentenced by the inquisition for his claim that the Earth was not a planet central to the universe; when this tree is already around the age of 300, Bertolt Brecht writes his poem 'to those born after us' in exile. '*What kind of times are these, when to talk about trees is almost a crime, for it is a kind of silence about injustice!'* [7] Now celebrating its 400th birthday, over bubbly wine and raspberry cake, it is time for a toast: may your offspring spread themselves far and wide across many different landscapes, after even you are gone; may your sons and daughters have the same longevity of life as you, testifying silently to every change around them: and may they shape cities, roads, and buildings according to their roots, trunks, and canopies, commanding the space they deserve at their own pace. If we were to be a bit mindful of the intergenerational timespan of trees' lives, it would reflect in the continuity of the urban environment left for those born after us. For a life according to tree time can remind us to connect us to lineages beyond the span of our own life, allow us to take in knowledge not conveyed otherwise, and reflect our impact on the environment we build for ourselves. Life along tree time can reflect our own silent resistance.

Summerlab Observants
Lua Vollaard wrote this text on the occasion of the 2021 ACT Summerlab in Ljubljana. As independent observant she was invited to participate in the Summerlab, and asked to create a critical reflection, based on the Summerlab's programme, participating artists and its social and ecological context. The Summerlab programme was organized by ACT-partner Bunkero and can be found here.

Lua Vollaard *is a curator, researcher and writer, connected to Stroom Den Haag and Eindhoven Design Academy's Critical Enquiry Lab.*

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Tiny Forests With Big Benefits

Native plants crowded onto postage-stamp-size plots have been delivering environmental benefits around the world — and, increasingly, in the U.S.

A Miyawaki Forest in Danehy Park, near Harvard University in Cambridge, Mass. Cassandra Klos for The New York Times

By Cara Buckley

Published Aug. 24, 2023 Updated Aug. 26, 2023

The tiny forest lives atop an old landfill in the city of Cambridge, Mass. Though it is still a baby, it's already acting quite a bit older than its actual age, which is just shy of 2.

Its aspens are growing at twice the speed normally expected, with fragrant sumac and tulip trees racing to catch up. It has absorbed storm water without washing out, suppressed many weeds and stayed lush throughout last year's drought. The little forest managed all this because of its enriched soil and density, and despite its diminutive size: 1,400 native shrubs and saplings, thriving in an area roughly the size of a basketball court.

It is part of a sweeping movement that is transforming dusty highway shoulders, parking lots, schoolyards and junkyards worldwide. Tiny forests have been planted across Europe, in Africa, throughout Asia and in South America, Russia and the Middle East. India has hundreds, and Japan, where it all began, has thousands.

Now tiny forests are slowly but steadily appearing in the United States. In recent years, they've been planted alongside a corrections facility on the Yakama reservation in Washington, in Los Angeles's Griffith Park and in Cambridge, where the forest is one of the first of its kind in the Northeast.

"It's just phenomenal," said Andrew Putnam, superintendent of urban forestry and landscapes for the city of Cambridge, on a recent visit to the forest, which was planted in the fall of 2021 in Danehy Park, a green space built atop the former city landfill. As dragonflies and white butterflies floated about, Mr. Putnam noted that within a few years, many of the now 14-foot saplings would be as tall as telephone poles and the forest would be self-sufficient.

Healthy woodlands absorb carbon dioxide, clean the air and provide for wildlife. But these tiny forests promise even more.

They can grow as quickly as ten times the speed of conventional tree plantations, enabling them to support more birds, animals and insects, and to sequester more carbon, while requiring no weeding or watering after the first three years, their creators said.

Andrew Putnam, superintendent of urban forestry for the city of Cambridge, Mass. Cassandra Klos for The New York Times

Flowers in the Miyawaki forest in Danehy Park, which includes 1,400 native shrubs and saplings, all thriving in an area roughly the size of a basketball court. Cassandra Klos for The New York Times

Perhaps more important for urban areas, tiny forests can help lower temperatures in places where pavement, buildings and concrete surfaces absorb and retain heat from the sun.

“This isn’t just a simple tree-planting method,” said Katherine Pakradouni, a native plant horticulturist who oversaw the forest planting in Los Angeles’s Griffith Park. “This is about a whole system of ecology that supports all manner of life, both above and below ground.”

Latest News on Climate Change and the Environment

A daunting hurricane season. A key area of the Atlantic Ocean where hurricanes form is already abnormally warm. This suggests an above-average hurricane season that may rival the busiest years on record.

The Griffith Park forest occupies 1,000 square feet, and has drawn all manner of insects, lizards, birds and ground squirrels, along with western toads that journeyed from the Los Angeles River, Ms. Pakradouni said. To get to the forest, the toads had to clamber up a concrete embankment, traverse a bike trail, venture down another dirt embankment and cross a horse trail.

“It has all the food they need to survive and reproduce, and the shelter they need as a refuge,” Ms. Pakradouni said. “We need habitat refuges, and even a tiny one can, in a year, be life or death for an entire species.”

Known variously as tiny forests, mini forests, pocket forests and, in the United Kingdom, “wee” forests, they trace their lineage to the Japanese botanist and plant ecologist Akira Miyawaki, who in 2006 won the Blue Planet Prize, considered the environmental equivalent of a Nobel award, for his method of creating fast-growing native forests.

Dr. Miyawaki, who died in 2021 at the age of 93, developed his technique in the 1970s, after observing that thickets of indigenous trees around Japan’s temples and shrines were healthier and more resilient than those in single-crop plantations or forests grown in the aftermath of logging. He wanted to protect old-growth forests and encourage the planting of native species, arguing that they provided vital resilience amid climate change, while also reconnecting people with nature.

“The forest is the root of all life; it is the womb that revives our biological instincts, that deepens our intelligence and increases our sensitivity as human beings,” he wrote.

Dr. Miyawaki’s prescription involves intense soil restoration and planting many native flora close together. Multiple layers are sown — from shrub to canopy — in a dense arrangement of about three to five plantings per square meter. The plants compete for resources as they race toward the sun, while underground bacteria and fungal communities thrive. Where a natural forest could take at least a century to mature, Miyawaki forests take just a few decades, proponents say.

A Miyawaki forest in New Delhi. Arvind Yadav/Hindustan Times, via Getty Images

Butterflies in the Miyawaki forest of Kalina Biodiversity Park at Mumbai University, which opened last year. Vijay Bate/Hindustan Times, via Getty Images

Crucially, the method requires that local residents do the planting, in order to forge connections with young woodlands. In Cambridge, where a second tiny forest, less than half the size of the first one, was planted in late 2022, Mr. Putnam said residents had embraced the small forest with fervor. A third forest is in the works, he said, and all three were planned and organized in conjunction with the non-profit Biodiversity for a Livable Climate.

“This has by far and away gotten the most positive feedback from the public and residents than we’ve had for any project, and we do a lot,” Mr. Putnam said.

Still, there are skeptics. Because a Miyawaki forest requires intense site and soil preparation, and exact sourcing of many native plants, it can be expensive. The Danehy Park forest cost $18,000 for the plants and soil amendments, Mr. Putnam said, while the pocket forest company, SUGi, covered the forest creators' consulting fees of roughly $9,500. By way of comparison, a Cambridge street tree costs $1,800.

"A massive impact for a pretty small dollar amount in the grand scheme of the urban forestry program," Mr. Putnam said.

Doug Tallamy, an American entomologist and author of "Nature's Best Hope," said that while he applauded efforts to restore degraded habitat, particularly in urban areas, many of the plants would eventually get crowded out and die. Better to plant fewer and save more, he said.

"I don't want to throw a wet blanket on it, the concept is great, and we have to put the plants back in the ground," Dr. Tallamy said. "But the ecological concept of a tiny forest packed with dozens of species doesn't make any sense."

Kazue Fujiwara, a longtime Miyawaki collaborator at Yokohama National University, said survival rates are between 85 and 90 percent in the first three years, and then, as the canopy grows, drop to 45 percent after 20 years, with dead trees falling and feeding the soil. The initial density is crucial to stimulating rapid growth, said Hannah Lewis, the author of "Mini-Forest Revolution." It quickly creates a canopy that shades out weeds, and shelters the microclimate underneath from wind and direct sun, she said.

Throughout his life, Dr. Miyawaki planted forests at industrial sites globally, including at an automotive parts plant in southern Indiana. A turning point came when an engineer named Shubhendu Sharma took part in a Miyawaki planting in India. Enthralled, Mr. Sharma turned his own backyard into a mini-forest, started a planting company called Afforestt, and, in 2014, delivered a TED Talk that, along with a 2016 follow up, ended up drawing millions of views.

Critics point out that because a Miyawaki forest requires intense preparation and exact sourcing of many native plants, it can be expensive. The Danehy Park forest cost $18,000 for the plants and soil amendments, plus roughly $9,500 for the forest creators' consulting fees. Cassandra Klos for The New York Times

Around the world, conservationists took notice.

In the Netherlands, Daan Bleichrodt, an environmental educator, plants tiny forests to bring nature closer to urban dwellers, especially city children. In 2015, he spearheaded the country's first Miyawaki forest, in a community north of Amsterdam, and has overseen the planting of nearly 200 forests since.

Four years later, Elise van Middelem started SUGi, which has planted more than 160 pocket forests worldwide. The company's first forest was planted on a dumping ground alongside the Beirut River in Lebanon; others were sown later near a power plant in the country's most polluted city, and in several playgrounds badly damaged by the 2020 blast at Beirut's port.

And Earthwatch Europe, an environmental nonprofit, has planted more than 200 forests, most of them the size of a tennis court, throughout the United Kingdom and mainland Europe in the last three years.

Though many of the forests are still very young, their creators say there have already been outsize benefits.

The woodlands in Lebanon have drawn lizards, geckos, birds and tons of insects and fungi, according to Adib Dada, an architect and environmentalist and the main forest creator there. In the West African country of Cameroon, where eight Miyawaki forests have been planted since 2019, there are improved groundwater conditions and higher water tables around the forest sites, according to Limbi Blessing Tata, who has led the reforestation there. Crabs and frogs have also returned, she said, along with birds that were thought to be extinct.

According to Mr. Bleichrodt, a 2021 university study of 11 Dutch mini-forests found over 1,100 types of plants and animals at the sites — kingfishers, foxes, hedgehogs, spider beetles, ants, earthworms and wood lice.

“A Miyawaki forest may be like a drop of rain falling into the ocean,” Dr. Fujiwara wrote in an email, “but if Miyawaki forests regenerated urban deserts and degraded areas around the world it will create a river.”

“Doing nothing,” she added, “is the most pointless thing.”

Cara Buckely is a reporter on the climate team at The Times who focuses on people working toward climate solutions. More about Cara Buckley

Topical Section 1: Visual

Section Introduction

As the mainstream game design world moves away from the pixel, I and many indie game designers move toward it. For a handful of reasons, some of which are purely artistic reasonings, others for its similarity to the module and the module's relationship with the real world. It is the aggregate of a much larger system. It is tiny and infinite simultaneously. It is a grotesque abstraction I seek to emulate in digital environments. A collection of pixels is a means to abstraction yet in a computation sense, it is definitive data that a system can use to animate change. I lean on the flicker of visual knowing for its open-ended-ness and invitation to the player’s imagination.

In digital environment construction, much research that has been done has been tied to the technological advances of the computer and thus the field rarely takes a chance to dwell in the medium it creates along the way. This section works toward creating a discussion of the visual of games and the medium historically. With an environment centered and designer mindset, constraints can be applied to the technological medium that tie the game’s visual to mechanical function and meaning.

The academic papers within research various conditions of visual design, from authenticity in independent games discussed by Juul to the utility of grids in architectural spaces by Katagiri et al. Nassauer studies the organization of ecosystems in relation to order, chaos, and societal expectations. Bao examines the temporal and emotional effect of art as drawn in pixel and vector format. Together, they establish implications of visual design in society and interactive media. The book review of *Thinking in Systems* is here as I hope to tie interactive media’s visual identity to systemic behavior.

My case studies consist of *Adventure, LODE, and Emissaries*. I've chosen these precedents for their visual abstraction and how limited or 'glitch'-like graphical representation can aid the designer while also engaging a viewer's imagination. *Adventure* was made in the 1970's and *LODE* was made in the 2010's, yet the contemporaries of *Adventure* carry similar visual weight to that of the newly contemporary *LODE*. *Emissaries* on the other hand is a live simulation that evolves continuously. Never once being static, its characters seemingly glitch or vibrate, just as everything in the universe continuously vibrates.

In today's technology, pixelated graphics are usually fabricated for kitsch, nostalgia, or other connotations given that screens have multiplied the number of pixels on screen to the point that they've disappeared. This section's design conjecture uses scales up pixelated graphics and lays vector and shader graphics over top of it to mix the old and new. The pixel medium inherently contains a grid which can coordinate the placement of vectors or shader graphics placed on top of it. This visual system has a sense of depth while the components on their own seem flat. I attribute this depth similarly to the complexity of ecosystems.

Altogether, these components celebrate the role of visual design and how it can be a starting point for environment centered media while engaging and relying on the viewer's imagination.

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[> jesper juul: text]

High-tech Low-tech Authenticity: The Creation of Independent Style at the Independent Games Festival

Juul, Jesper. "High-tech Low-tech Authenticity: The Creation of Independent Style at the Independent Games Festival". Proceedings of the 9th International Conference on the Foundations of Digital Games, 2014.

Pdf version.

Abstract

In game culture, in academic and popular commentary, *independent games* have been declared a major new development in video games in the last few years. At the same time, most academic and industry discussions state that it is impossible to describe independent games in a meaningful way. Counter to this, this paper examines the history of winning entries in the Independent Games Festival from 2000-2014 and identifies the rise of a specific visual *Independent Style* shared by many independent games, a style that is a *representation of a representation,* using contemporary technology to emulate visual styles from earlier times, including pixel style graphics, crayons and other analog materials. This visual style is meant to invoke a type of authenticity and "honesty in materials" that marks it as distinct from the alleged realism of bigger-budget titles. This type of strategy is associated with the contemporary maker movement, as well with 19th century ideas about arts, crafts, and architecture. It is a style that is not simply a natural expression of a particular method of game development, but an example of "authenticity work": a careful construction to appear as a counter to large-budget game productions, and to give the appearance of a direct connection between players and game developers.

This does not mean that Independent Style is a dishonest construct. Rather it enables video games developed with few resources to present themselves as, and be recognized as, the result of conscious decisions rather than of a lack of resources, while also in some cases giving developers a way to demonstrate a counter-technical expertise by using video game hardware and tools against the intentions of manufacturers (such as using 3d hardware to develop 2d games).

Keywords
Independent games, visual style, video game history, honesty, authenticity, DIY, Independent Style, craft.

The rise of independent games

By name *independent game* refers to the financial independence of the game developer, rather than to the design of the game. Yet we are just as likely to associate "independent games" with particular designs, people, distribution channels, and platforms. Certainly, with independent games, the assumed slick commercialism of both big budget and casual games is met by a counter-image of small, cheaply developed, more personal and experimental games [25]. While the name refers to the financial situation of the developer, it is also used more loosely to describe games made on small budget. In fact, most discussions of independent games start by the assertion that they cannot be defined:

- "It's a slippery slope trying to define indie gaming since there is a lot of discord in the game-making community". -Mike Gnade [24]
- "If independent games do exist, then they're independent because something about their economic, technological, or cultural status makes them so." -Eric Zimmerman [63]
- "Rather than arguing for a single definition of indie, this article examines the ideologies underlying the multiple definitions of the term." –Nadav Lipkin [37]
- "There is no point in seeking a formal definition or classification of 'indie games'" –Bart Simon [55]

It is true that simply describing the economic conditions of production does not exhaustively capture independent games [63], and commentators typically focus on the general vagueness of the label [24] or the futility in trying to define it [55]. Independent games have been compared to independent music and cinema [37] [63], as well as to punk music [54] with its rejection of polish and big budgets, and some proponents argue that independent games embody an authenticity not found in larger productions [17]. This paper proposes, not a definition of independent games, but a *description* of an influential visual Independent Style, a style that borrows from both the history of video games, and from the history of art and design.

As film theorist David Bordwell has argued, the study of style is a rich source for understanding the development of an art form – in all its complexity, with all its actors [10] – but the question of style has also sometimes been dismissed as an unimportant footnote to more important matters. However, style is a very concrete factor – games are developed for, and judged and grouped by their style, and to ignore this would be to render ourselves blind to the processes by which games are selected, celebrated or ignored. Hence we need to understand the history of style in independent games.

It is important to note that any *particular* independent game actually presupposes the *idea* of independent games. To develop independent games is to face a particular challenge: how can a game made on a small budget be perceived by players as something unique and new, rather than simply a game with too small a budget, a literally cheap version of a big-budget game? The Independent Style outlined here is a particular answer to this problem, because it signals that a game has *deliberately* been developed with a low-budget visual style, a style that would not be improved by a bigger budget. By emphasizing the small, personal and simplistic, Independent Style makes the claim that limited budgets are not a limitation, but rather a better, and more authentic, way of making games [50], and Independent Style is used by players to recognize a game as independent in a positive sense.

This focus on small productions, simple production and distribution, and the value of personal creation shows how independent games connect both to the contemporary ideals of the maker movement [20] [28], do-it-yourself (DIY) [56] and the locavore food movement, as well to older ideas such as those of the Arts and Crafts movement toward the end of the 19th century. The Arts and Crafts movement is usually understood as a reaction against industrial production ("machine production"), and as arguing for a return to craft and to small-scale production. In the 1888 essay "The Revival of Handicraft" [41], William Morris described the disappearance of handicraft in the face of machine production as "a degradation of life" and hoped, as the title suggests, for a societal and political revival of authentic workmanship where the individuality of the creator would once again shine through. Compare this to the way many independent game developers claim that their games – unlike the games made by large teams – reflect personal experiences, effectively longing to return to a more simple time in video game development, when games were made by small teams or a single person:

- "Indie games let me be a fan who is cheering on someone authentic and deserving".

–Dan Cook [17]
- “Speak from your heart. Honesty is extremely valuable when making [Indie game] art”.
–Edmund McMillen [38]
- “A much higher bandwidth relationship with art … that deeper and more niche personal relationship with the work”. [3]
–Robin Arnott
- “Why Being Poor and Having No Budget is Good For Making Games.”
-Petri Purho [50]
- “Being able to (or learning to) identify the individual style and growth of individual authors leads to … more personal games, more relevant games, more games with something to say.”
-Anna Anthropy [4]

These quotes show how such claims of personality, authenticity and honesty are common among independent developers. *Super Meat Boy* designer Edmund McMillen lists honesty as the most important trait of an independent designer [38], and developer Dan Cook stresses the authenticity of independent games [17]. Like the Arts and Crafts movement, this notion of independent games can therefore be said to embody a certain nostalgic or anti-industrial attitude. Where Arts and Crafts were against industrialization, independent games react to big-budget AAA productions. Arts and Crafts and independent games also share a set of moral-political-aesthetic claims. The claim in independent games, like in the Arts and Crafts movement, is not simply that independent games are *better products*, but that they are politically, morally and aesthetically wholesome: independent games are better, but developers will also lead better lives, and society at large will be improved by increased communication between people. A common criticism of Arts and Crafts has then been that the political goals were not met, but that “Craftsmanship becomes less a path to satisfying communal work than a therapy for tired businessmen”[36:xv]. I will return to whether this criticism applies to independent games.

My central argument here is that the combination of anti-industrial attitudes with modern technology is clearly visible in the visual style of many independent games. A visual *style* here means a particular way of representing a game world and its logic [31]. A quick glance at the well-known independent games shown in Figure 1 through Figure 3 gives an impression of similarity, though not in their visual style at first. Each game has a side-view perspective and builds on earlier games (*Super Mario Bros* [44] in the case of the first two and *Kirby: Canvas Curse* [27]), while adding twists both in graphical representation and gameplay.

Figure 1: *VVVVVV*

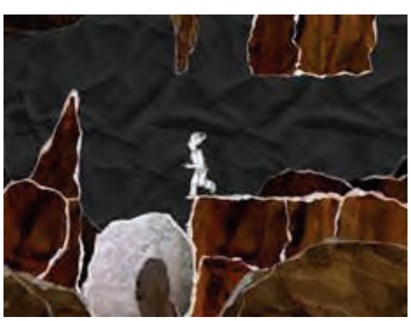


Figure 2: *And Yet It Moves*

Figure 3: *Crayon Physics Deluxe*

On the other hand, their visual styles *do* at first appear quite different: *VVVVVV* (Figure 1) uses a low-resolution pixel style that harkens back to an earlier point in video game history, the Commodore 64 games[1] of the 1980's [51]. This pixel style is perhaps the primordial independent visual style, also found in earlier games like *Cave Story* [58] (which references other hardware platforms). By **pixel style** I mean graphics where each pixel has been edited by hand, *and* where these pixels are enlarged, giving the appearance of a lower resolution than what is afforded by the platform the game is running on. But not all independent games share this retro 8-bit style. *And Yet It Moves* [13] shown in Figure 2 could not have been produced in the 1980's due to technological limitations, with the graphics appearing to be made out of cut-out paper, thus giving the impression of being analog rather than digital. Though *Crayon Physics Deluxe* [49] shown in Figure 3 also requires modern graphics capabilities in order to represent its crayon-based visual style, this style is again different from the paper style of *And Yet It Moves*. Is there any commonality in their visual styles at all?

The answer is that each of these games uses contemporary technology to represent a low-tech visual style. For *VVVVVV*, the style is 1980's video games; for *And Yet It Moves* and *Crayon Physics Deluxe*, the styles are torn paper and childlike crayon drawings. In their 2000 book *Remediation*, Bolter and Grusin make the broad claim that new media tend to remediate, that is simulate, earlier media forms [9]. As can be seen, this visual Independent Style hinges on a remediation of earlier styles in order to create something new and contemporary. Or put in another way: Independent Style is a representation of a representation; a high-tech representation of low-tech, and usually cheap, materials.

What Bolter and Grusin also say is that each new medium promises us a more immediate – transparent – experience, but also points to itself *as* a medium in the process [9]. It is easy to trace this line of rhetoric in the promotional campaigns for new consoles, which regularly promise more realism *and* emphasize the technology that allows a particular console to provide such alleged realism [32]. This shows that Independent Style represents a break with the idea that video games through technological progress are moving on a linear path towards realism. Independent Style is rather a deliberate attempt at going back in time, towards earlier representational styles – styles made from cheap materials[2] – that now appear as less realistic than what is promised by console manufacturers and big-budget game development. I will call this style **Independent Style** (capitalized), and it can be described like this:

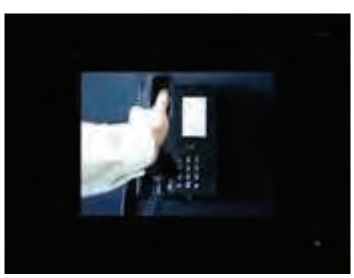
> ***Independent Style*** *is a representation of a representation. It uses contemporary technology to emulate low-tech and usually "cheap" graphical materials and visual styles, signaling that a game with this style is more immediate, authentic and honest than are big-budget titles with high-end 3-dimensional graphics.*

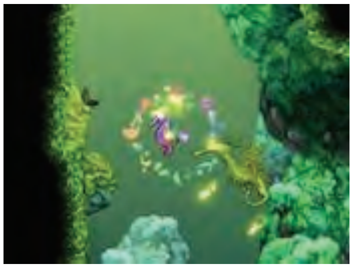
The historical appearance of Independent Style

"Independent game" therefore has three distinct meanings:

1. Independent as small and financially independent teams.
2. Independent as a moral-political-aesthetic claim.
3. Independent as a particular style.

Independent Style is the style that signals small teams, as well as authenticity and honesty. Before I further argue for this interpretation, let me first ask: what are the historical origins of this style? It is clear that many independent developers create games in other styles, but this visual style is predominant among well-known, and well-awarded, independent games. Is there a logic or necessity to this particular style, or is it an arbitrary construction, a style that was decided on simply to signal belonging to a particular subculture of game developers? To answer this, let me examine the Grand Prize winners of the annual Independent Games Festival (IGF)[3], not only because this is the longest-running major festival of independent games, but also because it *names* the games that it judges as exemplars of independent games. It is not that the IGF can tell us a final truth about independent games, but rather that the IGF has been a high-profile venue for the curation of a particular idea of what constitutes (and doesn't constitute) an independent game. It is therefore valuable to follow the choices of the IGF jury as the historical evolution of a particular conception of independent games. (Full disclosure: the author is also a jury member.)

Year	**Name**	**Screenshot**	**Visual style**	**Theme / gameplay**
2000	*Tread Marks*		3d	Tank battle
2001	*Shattered Galaxy*		Isometric	Strategy game
2002	*Bad Milk*		Photos rotating in 3d	Associational multimedia
2003	*Wild Earth*		3d	Animal safari

2004	*Savage: The Battle for Newerth*		3d	MOBA war
2005	*Gish*		Monochrome 2d / physics	Platform game
2006	*Darwinia*		Platonic low-poly 3d	Strategic war game
2007	*Aquaria*		Watercolor 2d	2d swimming
2008	*Crayon Physics Deluxe*		Hand-drawn 2d	Physics-based puzzle with drawing
2009	*Blueberry garden*		Hand-drawn 2d	Storybook platformer

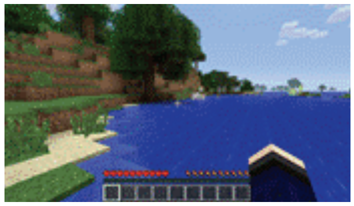
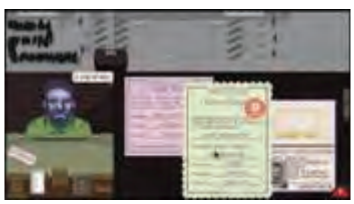
2010	*Monaco*		Pixel style 2d w/ lighting effects	Multiplayer top-down action
2011	*Minecraft*		Pixel style 3d	Quirky world-building
2012	*Fez*		Pixel style 3d/2d	Platform game with puzzles and 2d/3d twist
2013	*Cart Life*		Pixel style greyscale	Existential simulation of low-paying occupation
2014	*Papers Please*		(Mostly) pixel style greyscale	Existential simulation of menial job

Table 1: Independent Games Festival Grand Prize winners 2000-2014

As the table demonstrates, the IGF's idea of the independent game has evolved significantly during the history of the festival. This history can be divided into four different phases.

- **Before Independent Style**: 2000-2004 winners are not recognizable as having the Independent Style that I have outlined, but rather appear as small versions of bigger-budget games, with 3d graphics and presumably an intention of eventually acquiring publisher backing and distribution on physical media. Three of these games share a regular theme of armed conflict, but *Wild Earth* has a more "ecological" message (borrowing from the photography element from *Pokémon Snap*). The 2002 winner *Bad Milk* is a return to 1990's CD-ROM experiments.
- **The rise of pixel style**: 2005-2009 winners show the appearance of a well-defined *Independent Style* as 2d side-scrolling games with unique graphical representation. This style coincides with the increasing availability of non-physical game distribution, when it gradually became common for developers to distribute small-budget games globally. In visual style, *Darwinia* is the exception, with a type of "platonic" 3-dimensional graphics, arguably referencing the movie *Tron* and thus referring to the 3d visual style of an earlier time.
- **Pixel style in the 3rd dimension:** 2010-2012 winners show a movement beyond the 2d platform game, with *Monaco* as a top-down 2-dimensional game, and *Minecraft* and *Fez* representing the transformation of pixel style into the third dimension.

- **Serious themes:** The 2013 winner *Cart Life* and 2014 winner *Papers, Please* retain the pixel style, but represent use games for more documentary and political ends.

This history also points to differences within the high-tech representation of low-tech materials. Pixel style games refer directly, and probably nostalgically, to an earlier time in video game history. On the other hand, *Crayon Physics Deluxe* cannot point to an earlier point in time when video games were made with crayons. What is referenced is rather the general idea of playing with crayons and paper. The pixel style 3d games *Minecraft* and *Fez* also cannot refer to an earlier time when 3d games were commonly made out of large volumetric pixels (voxels), so like *Crayon Physics Deluxe*, the historical reference is somewhat counterfactual, but still suggests a simpler, if nonexistent, earlier technology.

Honestly old-fashioned and high-tech

Independent Style is most consistent on a visual level, but it has parallels in fiction (emphasizing irreverent or atypical themes) and gameplay (surprising variations on existing genres). Certainly, the platform genre has been overrepresented among independent games: in games such as *VVVVVV* and *Braid* [46], many conventions from the 1980's platform game are intact, but our expectations for how time and physics should work in such games are also challenged. Camper has examined such strategies in deliberate retro games [15], and describes how developers aim to capture a central experience of an old game, while adding contemporary developments in gameplay. In visual style, developers often add some contemporary flourishes such as particle effects or detailed animations that would not have been possible at an earlier time.

More poignantly, the use of physics engines in games like *Crayon Physics Deluxe* is a parallel to the visual Independent Style: this type of physics engine-based design comes across as immediate, simplistic and playful since it mimics a free-form play activity with bouncing objects. Yet it also requires modern processing power to work, and high quality physics libraries have only recently become broadly available. In this way it shares the high-tech-low-tech duality of the visual style, by being a thoroughly modern representation of a pre-digital play experience.

In the beginning, I discussed how the idea of honesty and authenticity connects independent games with earlier movements. Art historian Linda Nochlin has examined the idea of *honesty* in architecture and the decorative arts through the 19th century and writes:

> As early as the 1840s Pugin was inveighing against the dishonest concealment of architectural members, declaring that 'architectural skill consists in embodying and expressing the structure required, and not in disguising it by borrowed features'. [45]

This is a common type of argument, where it is emphasized that art or design should appear direct and without artifice express its own substantial structure and materials. It is a type of argument that has been used extensively in cultural history, including game design discussion [18].

In short, Independent Style follows this dictum of honesty in the *choice* of the low-tech materials that are represented, but contradicts it by *representing* these low-tech materials through high-tech tools. Independent Style effectively invokes and also contradicts these ideals of authenticity or honesty championed by earlier historical movements, but invokes an idea of make-do craft or expertise as a consequence: Independent Style consists partially of the "borrowed features" that Pugin was against in the previous quote; but particularly pixel style graphics can on the other hand require developers to work around default software and hardware affordances.

Craft: contradictions of the old and the new

If the low-tech and analog materials *represented* in Independent Style suggest authenticity and honesty, the representation of these low-tech materials can thus require a technical expertise that gives developers an opportunity to exhibit their ability to work against the intentions and default settings of hardware and software manufacturers. This points to three related contradictions in Independent Style: 1) between old and new technology, 2) between DIY and the expertise of the craftsperson, 3) between local and global distribution.

1) **The old and the new**: What can we make of the fact that Independent Style uses modern technology to imitate older styles of representation? Discussing the phenomenon of indie craft (today most associated with sites like etsy.com), Emily Howes examines the idea that crafting is a way of escaping the digital and immaterial, and that this can be seen as an echo of the Arts and Crafts movement, only responding against the digital where the Arts and Crafts movement responded to the industrial revolution [30]. Ultimately, Howes argues that contemporary indie craft is rather an example of how the "digital and the handmade are not in such opposition as might be assumed". In this case, Independent Style is a type of creative anachronism, where it is possible to reference past styles, pixels and drawings, without wishing for a complete return to some imagined pastoral past.

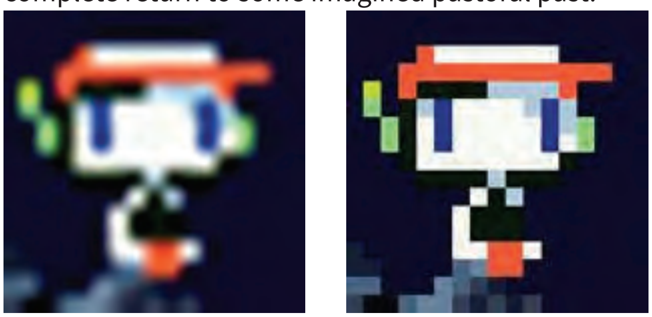


Figure 4: *Cave Story* character with anti-aliased and aliased graphics

2) **DIY and the expertise of craft**. If we focus on the low-tech materials represented in Independent Style, then we can chain Independent Style to a type of humble "lo-fi" DIY culture that emphasizes participation and personality rather than skill [56]. On the other hand, if we focus on either the high-tech representation, or the idea of the low-tech representation as something that enables developers to perfect minimalist game designs [43], then Independent Style becomes a place where developers can demonstrate their technical skills and their perfected craft. As Sennett describes this value, "Craftsmanship names an enduring, basic human impulse, the desire to do a job well for its own sake" [53:9]. As an example, the popular Unity3D engine will by default provide anti-aliasing when rendering, making pixel art appear blurry. Figure 4 shows the blurriness that the default settings of Unity3D would apply to the *Cave Story* main character (left), compared to how the character will look with the necessary adjustments to render pixel art with hard edges (right). The latter gives the appearance that the game is running on a different platform than it is, one material imitating another.

Figure 5: Unity3D *Angry Bots* tutorial game

In addition, before version 4.3, Unity3D did not explicitly support 2d games. Regardless, *Unity3D* is a popular platform for independent developers. This is also unexpected given how different the default game demo is from independent values. Figure 5 shows the gritty 3d military shooter demo *Angry Bots*, which from version 3.4 of Unity3D has been installed by default. Presumably, Unity Technologies feel that this shows off the tool well, but it is completely contrary to the Independent Style I have described here. It has therefore been up to developers to find ways to use Unity3D to create games in styles for which the platform was not designed or intended [59].

Such technical challenges are also tied to the ethos of sharing that Guevara-Villalobos has described in indie communities: “Within indie communities and networks, code sharing is a defining feature of game work. It fulfils different purposes, as it is both the product of the cultural ethos of the Web and a learning practice.” [26]. For example, the open source *Flixel* library [52] was created by *Canabalt* author Adam Saltsman, and provides a set of routines that makes it straightforward to make pixel style games in Adobe Flash, even though that platform by default encourages anti-aliased graphics. In this way, developers improve their craft and share tricks and tools with the community in order to overcome the default assumptions of the Flash software.[4]

The idea of craft has undergone a resurgence with books such as Sennett’s *The Craftsman* [53], and the recent anthology *The Craft Reader* [1]. These books trace a lineage back to William Morris, quoted earlier, and discuss the idea of craft as personal skill and contemplation. Compare this to game designer Anna Anthropy’s book *Rise of the Videogame Zinesters: how Freaks, Normals, Amateurs, Artists, Dreamers, Dropouts, Queers, Housewives, and People like You are taking back an Art Form*, where she promotes the idea of the DIY game that anybody can make, and compares them to the photocopied underground zine [4]. In this case, the pixel style that Anthropy’s games often use becomes a way of making video game development more accessible, as do other tools that she promotes, such as the text-based *Twine* platform [21].

Interestingly, Anthropy herself represents a hybrid position in that her games demonstrate considerable technical skill in referencing and combining elements from video game history, while she is also arguing for a type of development that is less reliant on such skills. As a type of middle ground, Westecott compares independent game development to craft as such [62], and notes how craft has often been associated with “women’s work”, and how mass production gradually devalued craft, associating it with the domestic sphere of women. Westecott also notes how independent games have the opportunity to bridge this division, but now face a potential division between amateur and professional independent developers.

The question of expertise also shows why independent games are not direct inheritors of a “punk rock” attitude [54]. When independent games are seen as examples of good craft, that is in direct conflict with the common perception that punk rock represented the idea that anyone could form a band. In some cases, the fact that independent games are small productions often made by one or two developers, means that they are discussed as prime examples of perfectly crafted small systems, “stripped town to essentials” [2].

3) **Local and global distribution**: Glenn Adamson defines *craft* as “the application of skill and material-based knowledge to relatively small-scale production” [1]. Given that independent games, and Independent Style, are highly dependent on the availability of digital (e.g. immaterial) global distribution of games, this creates a disconnect between the local, “small-scale” aspect of independent game development, and the global large-scale distribution that may follow. The short answer to this conundrum is that it *is* impossible for successful independent game developers to provide the type of personal connection and communication that the audience may expect from them, *as* independent game developers. The longer answer is that in independent games, the “small-scale” emphasis is on the

production rather on the distribution, so that this is not understood as the conflict that one might predict. The main alternate solution to the local-global dilemma is the “new arcade” [34], where developers emphasize the local and particular by avoiding digital distribution and rather only making a particular game available at single events, using custom non-distributable hardware.

Authenticity work

As we can see, the signals of honesty and authenticity come from the materials *represented* by the visual style (large pixels, paper, crayons), while the *representation* of the same style may sometimes be technically challenging, and thus give developers a chance to demonstrate their skills while employing a visual style that suggests that little skill is necessary.

A default critical response may be to declare this a type of paradox of authenticity [57] in that the low-tech pixel style and hand-drawn graphics that are meant to signal authentic, unadorned and honest game development – are not the least authentic, but entirely and deliberately constructed embellishments enabled by the high-tech representation. And it would be easy to make such a critical reading of Independent Style, arguing that for something to be perceived as authentic, it will have to exhibit the signs of authenticity, and these signs will often be deliberately *curated*, hence undermining the authenticity claim in the first place. Straub [57] quotes Jonathan Culler for making such a general argument:

> The paradox, the dilemma of authenticity, is that to be experienced as authentic it must be marked as authentic, but when it is marked as authentic it is mediated, a sign of itself, and hence lacks the authenticity of what is truly unspoiled, untouched by mediating cultural codes. [57]

Peterson takes this a step further and argues that authenticity should therefore be understood not as a property of something, but as “a claim that is made by or for someone, thing, or performance and either accepted or rejected by relevant others” [47]. Based on examples of authenticity claims in country music, Peterson names this “authenticity work” in order to describe effort made to make something be accepted as authentic.
This suggests Independent Style to be a cynical ploy, an artificial construction made to create a false impression, a collection of dishonest signs. It is of course perfectly possible to interpret Independent Style as such as cynical ploy, but my argument is that independent games are appearing in a cultural environment that supports authenticity claims – and as quoted, some developers certainly make authenticity claims in public statements. In addition, a critical interpretation would still overlook the fact that some signs require more resources than others. A large advertising campaign extolling the authentic virtues of wine from a particular region [6] is clearly expensive, but a pixel style signaling another kind of authenticity may be cheap. But if the claim of the independent game is exactly that of having virtue due to it having been developed with few resources, then the style that I have described here as a sign used to *signify* independent authenticity – that style *is* an *embodiment* of development on a limited budget. It is cheap to make, and cheaper to make than are expansive 3d worlds with high-end graphics[5]. Lipkin argues that the term “indie” has shifted from being a signifier of production to referring to a style [37], but I am arguing that it is both at the same time, and that the style itself refers to production methods. And even though Independent Style is a constructed signifier chosen to signify low-budget production, the concrete style also *enables* low-budget production.

For example, *VVVVV* developer Terry Cavanagh freely admits that the visual style for the game came about because of his personal limitations as a designer, where the self-imposed limitations of the retro visual style helped the development of the game.

> I don't have the technical ability to make my games look good, so I do what I can to at least

> make them look interesting. I find it easier to do this when I work within narrow limits - in VVVVVV, for example, I limited the background tiles for each room to just 5 shades of one colour, and then changed colours and patterns as I went along. [51]

The truth is two-fold here: independent development has to some extent followed the money and gravitated to the style that can be made on the smallest budget. But additional work is also employed in order to create the Independent Style that most directly signals authenticity and immediacy.

When I claim that this style *signals* honesty, I mean that this is plausible given its affinities to both historical and contemporary movements, and because this interpretation is supported by the public statements of several developers. It is unlikely that all developers choose this style because they want to signal authenticity – the style has also become a default style that developers can now choose simply because it is already common and well understood by developers and players alike.

Retro: Another Case of History Repeating?

Figure 6: *Hover Bovver*

Still, is there not a sense that all of this happened before? Compare *VVVVVV* to the 1983 UK home computer game *Hover Bovver* [40] shown in Figure 6. *Hover Bovver* is mostly made by a single person (UK developer Jeff Minter), features pixel style graphics and an idiosyncratic and non-heroic theme, in this case the mowing of the player character's lawn. In terms of visual style, theme, gameplay, and development conditions, this game is eerily similar to many contemporary independent games.

But *Hover Bovver* demonstrates what we can call a *Pierre Menard*-effect. In Jorge Luis Borges' short story *Pierre Menard, Author of Don Quixote* [11], the titular character decides to write – from scratch – a text that is word-for-word identical to *Don Quixote*, without having read the original novel. Borges' narrator then compares the style of the two identical 20th century and 17th century texts – and concludes that they are radically *different* since the original *Quixote* was written in the language of the author's time, but the newer *Quixote* is archaic and mannered. Which is to say that the simple pixel style of many contemporary independent games is deliberately dated, an archaic throwback to an earlier time in the history of the video game, whereas *Hover Bovver's* 1983 visual style was contemporary. In fact, *Hover Bovver* does not use pixel style in the way I defined it previously, given that its pixels are displayed in the native resolution of the hardware, rather than being enlarged as in *VVVVVV*. A particular visual style does not *mean* the same thing when executed twice, 25 years apart.

While many contemporary independent games may be associated with early Nintendo culture due to the common use of platform games as inspirational genre, I believe that independent games owe more to computer-based games in general, and to European video games of the 1980's in particular. This is in part a function of the fact that US and Japanese video game development at the time was mostly directed toward consoles, while European video games were mostly developed for home computers. This meant that from the success of the Nintendo Entertainment System and on, many US and Japanese games were subject to approval by platforms owners, while more European video games could be freely created and distributed. Furthermore, and possibly as a result, many European video games of the 1980's share a thematic irreverence that was rare in console games [35] [19].

As Bennett Foddy has argued, independent game development has been a constant in the history of video games, but the idea of calling it "indie games" is quite recent [23]. What *is* new is the appearance of a style that references earlier (factual or counterfactual) times in game history. Interestingly, game-derived pixel style was popular in web design already around 1998 [22], before it became a popular game style, suggesting that contemporary pixel style is dependent on a distance (temporal or in media) to the materials and styles it references. Distance is necessary for users to see a style as a deliberate choice.

Games for the connoisseur?

It could be said that the rise of independent games is a logical consequence of the fact that video games are now being played by more than 50% of the population in many rich countries [48]. It used to be that playing video games was a differentiator, but now a new differentiator is needed, and (the idea of) independent games serve that need. In her book *Realism*, Linda Nochlin argues that in art, "the creation of the avant-garde was the mirror image, the precise response to the emergence of the mass Philistine audience" [45]. Some independent and art games can be seen as a similar response to the broadening of the video game audience, a way for self-identified game connoisseurs to develop a sense of having a particular and refined taste. This is the fourth contradiction in Independent Style: that this visual style can both work to democratize game development by enabling DIY development and to rarify game consumption, by catering to the tastes of a selected few. This contradiction is also tied to the amateur/ professional divide, where *Minecraft* has sold millions of copies, while more experimental games are only played by a small audience.

I have not defined independent games, but rather described a central Independent Style curated by the Independent Games Festival, a style that is shared by all IGF Grand Prize winners since 2005, as well as by many other well-known independent games. This style does not *define* indie, but developers use it to *signal* indie (financially and as a moral-aesthetic-political statement). I do not think that all developers use Independent Style with this intention, or in the belief that this is the statement they are making, but Independent Style is likely common *because* it signals and ties into contemporary ideas about local, particular, small-scale and personal production.

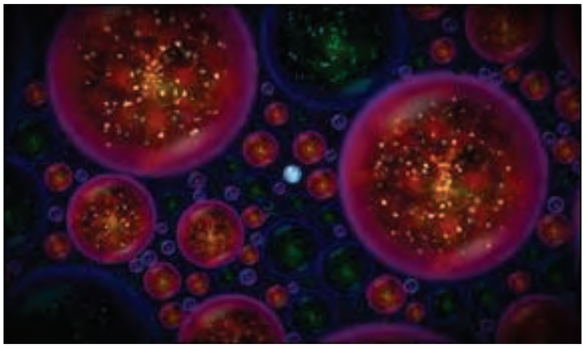


Figure 7: *Osmos*


Figure 8: *Journey*

To name some games often referred to, and awarded, as independent, yet not sharing this style, Figure 7 shows *Osmos* [29] which while 2-dimensional, is oriented towards the affordances of contemporary hardware rather than towards the emulation of an earlier visual style [6], and Figure 8 shows *Journey* [60], a 3-dimensional game that does not remediate any earlier visual style either. Of course, given enough time, even currently high-end graphics effect (such as *bloom*) of contemporary big-budget titles may eventually be used by a future independent game developer as a way of signaling a simpler, more honest time in video games [7].


Figure 9: *Braid*

Another prominent game usually referred to as independent, but which uses a particular variation on Independent Style, *Braid* [46] shown in in Figure 9 uses contemporary graphical tools to give a (perhaps simplistic) appearance of expensive materials associated with fine art [8]. The style and materials represented here are not improvisational and cheap, but rather invoke something expensive or high-brow, matching the lofty aspirations of the game developer [8].

Roland Barthes once argued that imitation materials are “bourgeois” and have traditionally “aimed at reproducing cheaply the rarest substances, diamonds, silk, feathers, furs, silver, all the luxurious brilliance of the world.”[5:98]. And it is surely the case that the cheap imitation of expensive materials is associated with poor quality and poor taste, as exemplified in faux wood, vinyl siding, or plastic jewelry. Independent Style is then the opposite: the use of expensive (or at least high-tech) materials to imitate cheap materials. If the use of cheap materials to imitate expensive materials is associated with low-brow, taste, then the use of expensive materials to imitate cheap materials is possibly associated with a modern and “sophisticated” taste. The art works of Jeff Koons are good examples, using expensive materials such as stainless steel to reproduce cheap balloon animals.

Independent Style is a positive force in that it supports the creation of small-budget games that players recognized as belonging to a particular well understood (and promotable) category [9]. However, Independent Style was also part of a “tyranny of pixelated platformers” [33], when many games lauded as independent also seemed to become quite similar. This shows the inherent tension if a movement for dynamic innovation in games congeals around a well-defined style, regardless of whether that style is explicit or implicit, agreed upon or not. It also follows that it would be worthwhile to compare IGF winners to games selected and promoted in other venues and countries. In addition, future variations of Independent Style are likely to change as more modern visual styles become sufficiently distant that they can be invoked, no longer signaling limited budgets, but as conscious choices referencing an earlier, simpler time in video game history.

Figure 10: *Chivalry: Medieval Warfare*

It is clear that small independent developers need not build their games around this particular Independent Style. A number of independent developers rather build “regular” 3d games in genres not seen as commercially viable by big publishers. *Chivalry: Medieval Warfare* [61] shown in Figure 10 is an example of this strategy. Such games are rarely promoted or awarded by independent game festivals. They are reminiscent of the early 2000-2004 phase of Independent Games Festival winners, before the rise of Independent Style, where a festival such as the IGF was seen as a stepping stone towards acquiring publisher support and distribution on a physical medium. What has changed, of course, is that such games are now distributed from web sites and online channels like Steam.

Conversely, though Independent Style enables low-budget development, there is nothing to prevent a bigger-budget production from using the same style, even if there are fewer financial reasons for doing so. As an example, the high profile (if medium-budget) PlayStation 3 game *LittleBigPlanet* [39] is based on high-end 3d representations of handmade materials such as cloth, thread, buttons, and stickers. The Lego Company similarly publishes Lego games built on existing franchises such as *Star Wars*, and uses 3d graphics to represent the low-tech brick-based representation of the *Star Wars* universe. Outside games, the directors of the *Lego Movie* “wanted to maintain the crude look of Lego figures and the limitations of the toys” [42].

Though the idea of independent games is by name tied to the economic and legal realities of game production, I have here talked about the components of a central Independent Style, a particular style that is not a necessary reflection of small-budget game development, but is rather a style deliberately designed to *signal* a particular small-team ethos. It is a style than can work as an enabler of small-budget productions, but game developers will sometimes put in extra effort in order to use this style. This is the dual nature of Independent Style, the high-tech representation of low-tech and low-budget materials.

Independent Style is a construct, but it also genuinely represents a cheap way of developing games, and its popularity makes it possible for developers to develop low-budget games that are understood by players not as cheap games that would have been better had they had a bigger budget, but as games that embody a particular style, and belong to a new type of video game.

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Notes

1. While Cavanagh explains [51] that *VVVVVV* refers to Commodore 64 games, the game's use of single-color sprites suggest that he is thinking of games such as *Manic Miner* and *Jet Set Willy* which were converted from the ZX Spectrum, and hence use a visual style common on that platform.

2. The use, or referencing, of cheap materials can be compared to the Italian *Arte Povera* movement in art.

3. http://www.igf.com/

4. The open source *Box2d* physics library [16] used for *Crayon Physics* is similarly used by many independent games.

5. The economy of "minimalist" visuals are also discussed by the *Osmos* developers [29].

6. The visual style of *Osmos* could also be interpreted as a deliberately old-fashioned flat 2d-blending style enabled by early 3D graphics cards, even if the temporal distance is quite short.

7. The 2013 *Thirty Flights of Loving* [7] is based on the 1997 3d engine from *Quake II* and its somewhat old-fashioned 3d graphics thus already arguably signal that the game belongs to an earlier, simpler time. Similarly, the game *Tuning* [14] references low-res 3D graphics.

8. IGF winner *Aquaria* also references painting, but in *Aquaria*, the style referenced seems to be children's books rather than fine art.

9. The acceptance of Independent Style is not universal, but the popularity of independent games such as *Minecraft* demonstrate that there is an audience that understands this style. When Independent Style is *not* accepted, responses sound like the tech commentator who stated that "Hey, Minecraft: 1993 called and they want their hideous graphics back!"[12]

Grid as Memory in City and Architecture

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Abstract. The architects had been attracted by grid systems and applied grids into realized architectures. We published *Grid on Architecture* in 2018 and discussed the relationship between the geometry of the grid and architectural works. In this study, we reckon the meaning of the grid in city and architecture by comparing game and toys with the grid. First, on reconsidering contemporary architectural theories, the grid, regarded as the "sea", is associated with architectural monumentality, isolated but inside the city, regarded as an "island", which makes us recognize the city and keep in the memory. We discuss the gameboard of the grid and brick toy. We can say that the game board grid is a "closed grid", for its isolated world inside from contexts outside. On the other hand, brick toy like *Lego* is regarded as an "open grid", for its multiplying square or cube system. Then, we discuss that these two ideas can also be seen in the idea of the city and architecture. In this sense, closed grids are seen in the ideal city of India and China, and open grids in an expansion of urban infrastructure, for example, *Cardo* and *Decumanus*, and Barcelona plan of Cerdà. After that, it treats how contemporary architects translated urban grid to their works on the real map.

Keywords: Grid · Memory · Design · Architecture · City

1 Grid in Design

Human beings have designed the geometry of the grid, from small toys to architecture, to urbanism. A grid is a simple geometric shape of a repeating pattern formed by intersecting a plurality of lines at equal intervals at right angles or diagonally. Because of its homogeneity, it is sometimes perceived as a homogeneous space or a uniform and boring space. However, if you look closely at an object made of a grid, you will see a variety of interesting details such as the shape and appearance of the squares separated by lines, the size and extent, and the center and edges of the area. Some of them were

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intentionally created, while others were inevitably or accidentally created about parts other than the grid.

Like Periodic Table, Calendars, and address books, the Cartesian grid helps us understand an amount of information in one sight. From virtual stuff like table games in Japan, toy bricks, and *Mandalas*, we use the grids, and the lattice systems to recognize the world. (Fig. 1) As far as design, "Grid" includes not only Cartesian lattice as an orthogonal coordinate system but also several patterns of the repetition of lines that have the same distance as a polar coordinate system.

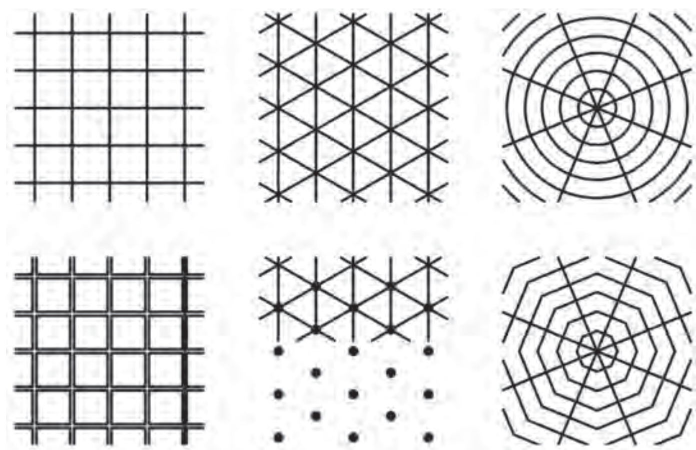

Fig. 1. Example of grid designs by human being

However, why do we apply the geometry of the grid to designed works?

In the study, we focus on the meaning of the grid as memory in architecture and cities. For the designs made by human beings in quotidian things, we remember that human beings used grid from small things to huge planning. In this research, we will discuss the grid-like spaces that exist on various scales in various environments created by humans, from virtual game-boards to real ones such as cities.

2 Grid in Contemporary Architectural Theory

Pier Vittorio Aureli, an Italian architect-theorist, discussed that the grid as "sea" in architecture is associated with politics of land possession. (Aureli 2018, 139) Aureli pointed out that grid at the urban scale has been used as a composition of appropriation of land and people have been obliged to obey the law of asymmetry political balance with subdivision of grid in the city as land possession. Expounding Aureli's critical view, in terms of architecture and city, people could not escape the composition of appropriation with the geometry of the grid. When we design architecture, we can communicate with each other with a comprehensive schéma of the grid, using standard lines, plan of *ramen* frame, and square windows aligned in the grid. For Aureli, grid system such as *Cardo* and *Decumanus* is regarded as urbanization, and he put importance on architecture as the island inside the expanding grid.

On the contrary, Andrew Witt reported his chronological view in terms of the relationship between mathematical formulation and modern architectural design. (Witt 2021, 275) According to Witt's view, from the 1970s to the 1980s, the cubic grid had imported economic patterns of thought into architecture as a unit of measurement and simulation, and even as a game like framework for economic or political choice. In contrast of Aureli's view of grid as land possession at urban scale, Witt insisted that cubic matrix only stared to show importance in 1930's and became tacit social system or a mathematical equivalent of an idealized economy (Witt 2021, 276).

The difference of political position between the two, although it might be derived from European Marxist position of Aureli and American Non-Marxist position of Witt, come from the difference of architectural scale of their views. Aureli focused on the large range of chronological culture of human habitation in the terms of urban scale and dwelling, while Witt focused on how human being design with formulation of cubic matrix in terms of architectural scale and idealized form. In Aureli's viewpoint, it is strongly premised that the primitive form in the collective memory – on which Aldo Rossi had put importance in the architectural design – should have been observed in any cultural traces of dwelling. However, in Witt s viewpoint, after the appearance of Modern geometrical culture for design, more and more human beings have applied mathematics into architectural design for investigating new architectural forms, molecular structure-like architectures of Louis Kahn's and Metabolist Movement.

3 Grid of Architectural Design and Exception in the City

Architects have struggled to design inside of the existing city inside the politics or power, because of large scale of material, size, and costs. Aldo Rossi, who was one of the most influential architect-theorists in the twentieth century, designed architectural projects in his youth with Gianugo Polesello and Luca Meda. Polesello, Rossi, and Meda made a project for *Centro Direzionale di Torino* in 1962.

According to Aureli, the project of the building of a 320 m square ring with a 280 m huge courtyard represents not only extrusions of the chessboard of grid outside of Turin, but also a form of exception, for being located on the periphery of the city. (Aureli 2008, 67.) Their project for a new office and directional center, about which Aureli indicated that the three architects had revealed the concealed power of the dominant class in those days with rigorous and simple geometry, was derived from the existing building inside the grid of Turin, *Mole Antonelli*ana (Fig. 2).

The high building with brick over 100 m height grid represents the state of an exception inside the city, which causes the inversion of negative and the positive of our recognition of the city. In other words, Mole Antonelliana is only a monument in the grid of the historical city, but acts as the essential reference for the whole grid of the Turin. They understood the effect caused by the relationship between monumental existence and the city grid, and applied it to their non-realized city-center outside the city, associating the concept of New *Centro Direzionale* with the *Mole Antenelliana* as the exception inside the Turin grid. (Fig. 3).

Fig. 2. (left). *Mole Antonelliana.* Image: author

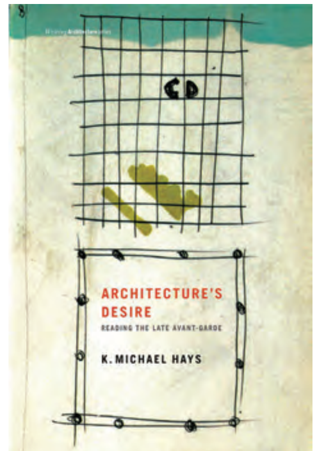

Fig. 3. (right). Rossi's drawing of the City grid of Turin with concept of *Centro Direzionale* Image cited from https://mitpress.mit.edu/books/architectures-desire, last accessed 28 February 2022.

4 Defining Its Monumentality with Grid

Aureli is not only influenced by Rossi but also by Gianugo Polesello. Polesello, who was one of his most important collaborators of Rossi, put importance on the city grid for architectural design. In the project for *Centro Direzionale di Firenze* in 1977, Polesello aligned nine towers in 3 × 3 square. (Fig. 4) Also, Polesello had tried to apply 3D grid-lattice of cubes in his architectural design (Mase 1994: 17–18) Mase Masahiko reported that Polesello had used a 15m grid with these standard lines (15 m = 3.75 m × 4 or 3 m × 5 = 15 m) both in the plans and the sections. (Mase 1994: 17, 27) In the Project of *Centro Direzionale di Firenze* (1977), Polesello and his collaborators designed nine towers with 15m grid.

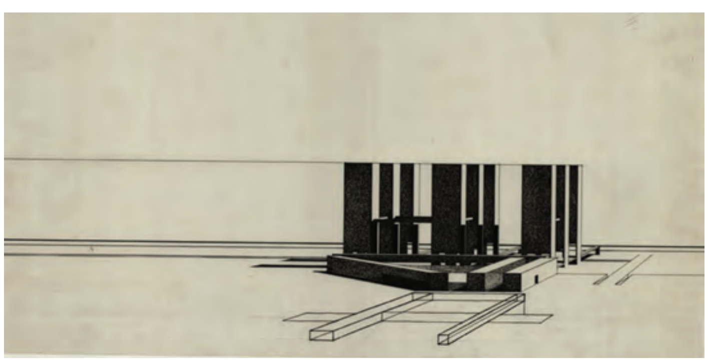

Fig. 4. Project for centro Direzionale di Firenze (1977). Image cited from Polesello (1982), p.53.

Fig. 5. Isometric projection of a 3D model of the structural frame of *Centro Direzionale di Firenze*. Image: author

In the project for the new city center of Florence, each tower is rigorously aligned in 3D-lattice of cubes of 15 m × 15 m × 15 m, supported by the same structure-frame made from steel and concrete of the square section of 1 m × 1 m. (Fig. 5) In some sense, 3D-lattice of Polesello was amplified with squares and cubes into the structure-module of the building, which was engraved in the imaginary city grid.

In the work for Florence, Polesello tried to connect structural frame and architectural design in as a purist way as possible, by associating the 3D lattice of the cube with a ramen frame of steel and concrete. The grid of the cube towers is geometrically and rigorously defined and then would operate the existing periphery around *Centro Direzionale* to prevent over-development of the land for its monumentality. Thus, what Polesello discussed is “their sense (of the already-given) of monuments, to regard/see isolated or approached, grouped” (Polesello 2000, 105) means that the architectural monumentality of simple geometry acts as “a fact” that exists for a long time ever before inside the city.

Moreover, Aureli and Tattara, who were taught by Polesello and Rossi at IUAV University in Venice, co-founded the office called DOGMA and designed the *City Wall* with Office Kersten Geers Devid Van Severen. (Fig. 6) The cruciforms of buildings make huge square spaces and restrict the development of the space. This urban plan shows that rigid and rigorous geometry urges us to keep the monumentality even though it represents the open grid system.

Fig. 6. *City Wall*. Image traced by authors from Dogma's project collaborated with KGDVS.

5 Grid of Game Board: Closed Grid

Why are architects attracted by the grid for the design? Inspired by Cristian Norberg-Schulz, Kishida (2012) redefined the idea of *schéma* for architectural design. Kishida points out that *schéma* cannot be invented but be held in human existence as a simple scheme (not in an iconic diagram) and points out that the grid is one of the most communicable *schéma* for architects to design forms.

Not only for architects but also non-architectural people, the *schéma* of the grid is effectively communicable. The board game is a comprehensive example. The game boards with planner grids make human beings understand the fictional system with Cartesian coordinates to define where the agents are located. For example, *Wordle,* the web game which is updated as a daily quiz, uses a 5 × 6 grid on which the player can put the five-letters-word in one time and try six times at maximum. For example, the upper word "WIRED" is incorrect but the letter "R" (yellow square) is included somewhere in the correct answer except for the third letter. (Fig. 7) Next, the word "ROAST" is also incorrect but the letters "R", "O", and "T" are included in the different positions. If we guess a correct position with the correct alphabet in one word, the squares highlight green, as the "T" and "O" in the third row. Finally, the player can find the correct answer as "THORN" with all five letters with green squares in the day.

Fig. 7. Web game in contemporary. Image: author on the *Wordle*

The game *Wordle* shows a simple connection between the player and the interface of the grid, where people put each trial on the one grid of 5 × 6. The correct answer is changed every day and one player had only one chance to guess in one day. Even though we had known the correct five-letter word, it is possible to guess the answer. Indeed, we can seek the five-letter word in the internet or web dictionary.

In this sense, *Wordle* is an open-resource-game, because we solve the game by investigating other resources. The grid of *Wordle* represents a rigid chance to enter the five-letter word six times maximum but the time to access information is premised on each chance to enter the word.

The grid in the game represents the stronger rigidness of the rule if the other player joins the game of the grid. *Senet,* in the New Kingdom of Ancient Egypt, has a gameboard of a rectangular grid of 3 × 10. (Fig. 8) In the game, the two players compete on the game board like snakes and ladder. The original rule is unknown for no records have ever been discovered. However, some have attempted to reconstruct the rules and it can be explained through Kendall's rule as below.

As with numbered and gridded squares, both players have five pieces in the first row of 1–10 by turn. (Fig. 9) Then, one player put each piece on 1, 3, 5, 7, 9, and the other on 2, 4, 6, 8, and 10. All the pieces run toward the goal of square 30 and when a piece arrives at the goal or particular squares, the player can remove it from the grid board. Finally, the player who removes all the five pieces will win.

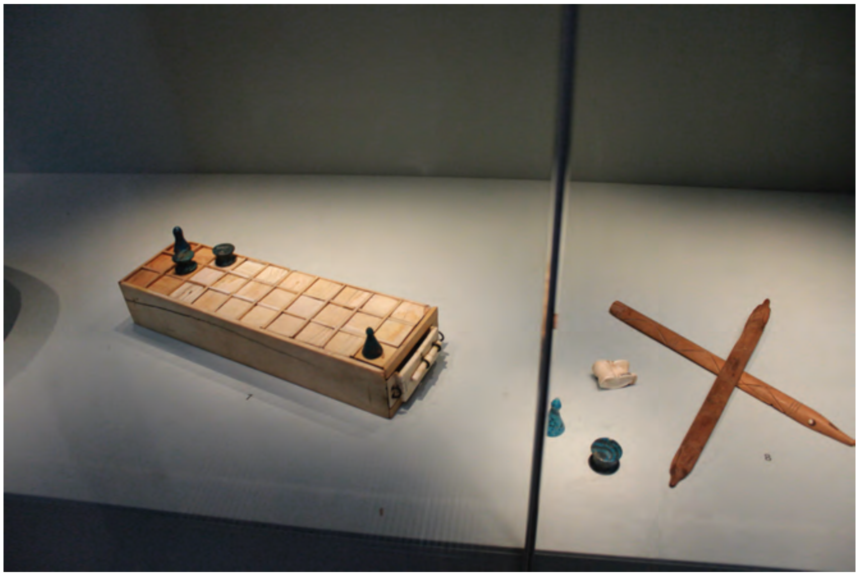

Fig. 8. Table game in ancient Egypt, *Senet*. Image: author

1	2	3	4	5	6	7	8	9	10
20	19	18	17	16	15	14	13	12	11
21	22	23	24	25	26	27	28	29	30

Fig. 9. Grid order of *Senet,* Image: Public domain

It is different to regard grid systems as a mass of squares or textile of vertical and horizontal lines. For example, the game of *shogi* in East-Asian culture has a 9 x 9 grid in which the pieces are put on each square, while the pieces in the game called *Go* are put in the cross points 18 × 18 grid. (Fig. 10).

The grid game board of each game can be said as a "closed grid", for they make a world system inside the game board, isolated and separated from the other system. As if they are "islands", the grid game boards urge us to act according to the system inside.

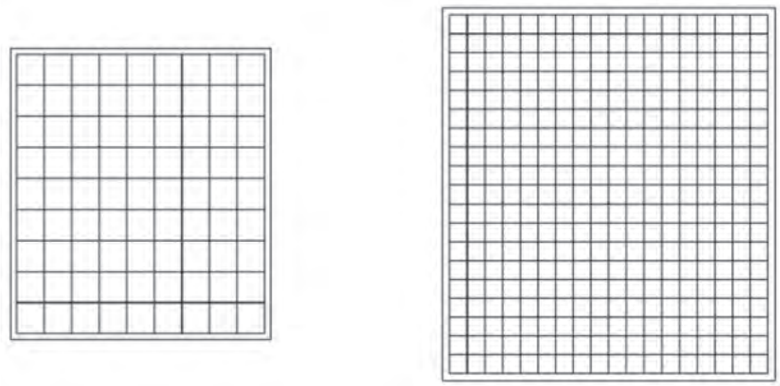

Fig. 10. Grid board of *Shogi* (left) and *Go* (right). Image: author

6 Grid of Brick Toy: Open Grid

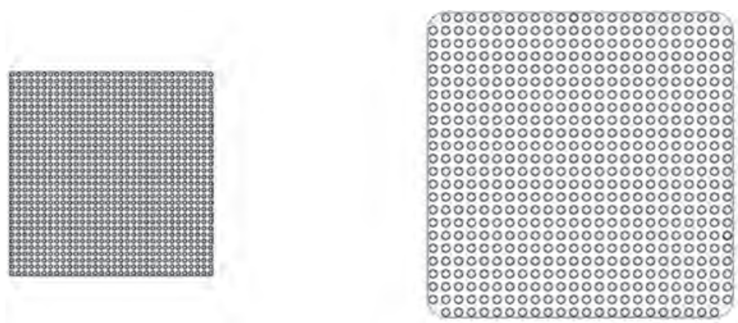

Fig. 11. The base plate of *Lego* (left) and *Diplo* (right). Image: author

The block of Lego is a systematic toy that can be made into various things by assembling several types of inset blocks. People put the studs on one side of the basic rectangle at an 8 mm pitch and fit the studs in the gaps on the other side to assemble firmly. (Fig. 11, left) There is also a series called Diplo that uses blocks larger than those of Lego. (Fig. 11, right) The block system of Diplo is composed of 16 mm studs, which is adapted to the system of 8mm studs of Lego. This is why Lego blocks with Duplo blocks can be mixed. In this case, although they are limited as base plate, the grid of bricks can be said as an "open grid", which enables us to compose things by extracting the system of 3D-lattice of bricks, which is defined in 2D-Grid in the campus, the standards of grid urge us to understand staffs as the composition of divided cubes and expand the composition inside the grid system.

7 City Grid: Closed Grid and Open Grid

Considering these games with grids, we can say that the two types, of closed and open, grids, enable us to recognize the world. The closed grid would work as if it were the boundary of the city wall and the open grid as a system of expansion in the land organization and occupation.

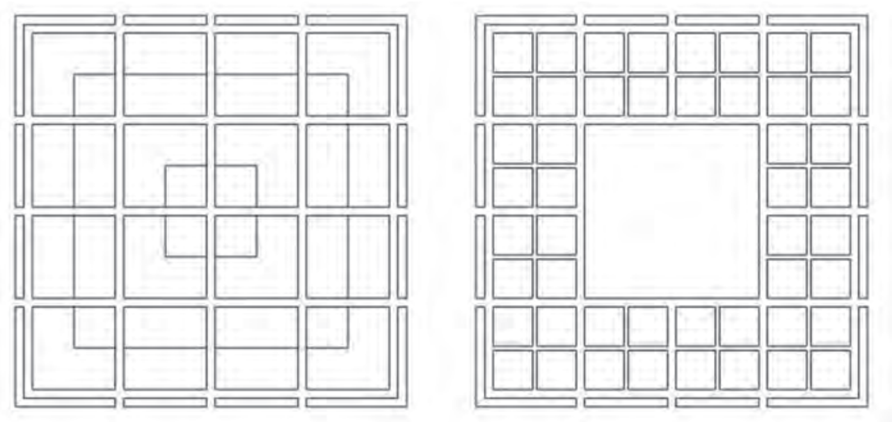

Fig. 12. City grid in ancient India (Left) and China (Right) Image: author

The two types of the grid can also be seen in the architectural ideal city. Since ancient times, closed grids (square design) have been used in urban design. In ancient India, the book *Alta shastra* states that the city should be surrounded by the city walls, and divided by three main streets vertical and three horizontal. The city was sectored in a 4 × 4 grid. (Fig. 12, left) This grid is supposed to be derived from *Mandalas*, the painting of grid composition with the Hindu Gods. (Fig. 13) Besides the ancient Indian concept of the city, *The Kaogong Ji* (考工记)*, the Record of Trades, Records of Examination of Craftsman, Book of Diverse Crafts or Artificers' Record*, during the Spring and Autumn period in China, states the grid of 4 × 4, similar to the grid in Ancient India. In ancient China during the period, between main streets or main streets and the one side of the wall, the street appeared and the grid was rendered from 4 × 4 to 8 × 8 grid. (Fig. 12, right) The concept was integrated into East Asian countries, for example, in ancient Japanese cities of the 8th century, Nara (old name: *Heijo-Kyo*) and Kyoto (old name: *Heian-Kyo).*

These ideal cities with a grid for the concept of geometrical reference of the powerful city with an orthogonal coordinate system. Also, there are examples of the ideal city with a polar coordinate system, for example, the Plan of Sforzinda made by Filarete and Palmanova City in Italy.

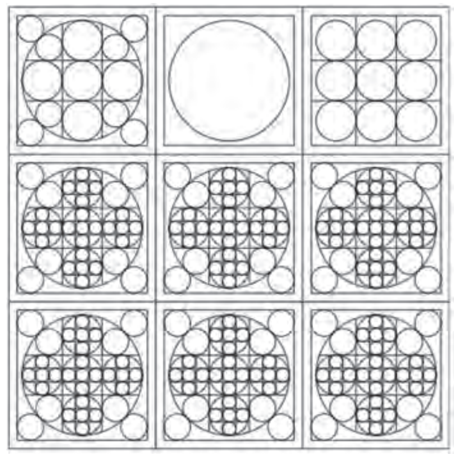

Fig. 13. Mandala in grid.Image: author

The ideal city with the grid is defined by the walls and makes the boundary as if they were an island. On the contrary, the grid system of *Cardo* and *Decumanus* in the Ancient Roman empire works as an expandable system with enlargement of the state power, as if it were "sea". The expanding system of the grid is shown in Ildenfons Cerdà's grid of Barcelona and Colonial cities, to which Aureli indicated urbanization (Aureli 2011, page.x.) The open grid works as a system in the expansion of infrastructure and circulation, for example, Hausmann's reconstruction of Paris as a polar coordinate system.

8 Grid as Memory in Architectural Design

Finally, we can say that the grid system has two faces; one is a resource of the standard line, defined as an open grid; the other rigorously defining razor of the stuff or things with boundaries, defined as a closed grid. These two faces mix each other, then compose our cognition of the quotidian stuff from the small to the huge.

At the stake is that the grid helps us keep the stuff in the mind or recognize things to recompose in the memory. Although the grid strictly works as a system in the city, as if it were the "sea", the geometrical boundary of architecture can be defined and work as an "island." In this meaning, the grid acts not only to integrate architecture as an "open grid" but also to separate itself from the others and underline architecture itself. That might be why we keep using the grid and memorize things with the grid, even though it is boring, too much familiar, mediocre, or commonplace.

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Messy Ecosystems, Orderly Frames

Joan Iverson Nassauer

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Abstract: *Novel landscape designs that improve ecological quality may not be appreciated or maintained if recognizable landscape language that communicates human intention is not part of the landscape. Similarly, ecologically valuable remnant landscapes may not be protected or maintained if the human intention to care for the landscape is not apparent. Landscape language that communicates human intention, particularly intention to care for the landscape, offers a powerful vocabulary for design to improve ecological quality. Ecological function is not readily recognizable to those who are not educated to look for it. Furthermore, the appearance of many indigenous ecosystems and wildlife habitats violates cultural norms for the neat appearance of landscapes. Even to an educated eye, ecological function is sometimes invisible. Design can use cultural values and traditions for the appearance of landscape to place ecological function in a recognizable context. I describe several examples of cultural language "cues to care" that provide a cultural context for ecological function, and I demonstrate how these cues can be used in design.*

> *. . . A continuous reframing of the phenomenon as (a) whole becomes a part serves to overcome the inertia of certainty.*
>
> —*Sidney K. Robinson*
> Inquiry in the Picturesque

Ecological Function, Cultural Perception

Ecological quality tends to look messy, and this poses problems for those who imagine and construct new landscapes to enhance ecological quality. What *is* good may not *look* good, and what looks good may not be good. The distinction between function and appearance may distress idealists who regard presentation as dissembling, but it is intrinsic to the concept of design, in which each landscape is recognized as one of any number of possible designs for a particular place. Landscape architects may consult the genius of the place, but they do not expect the genius of the place to design it.

However, even designers may become strangely submissive in the face of nature's genius, sharing in a common popular delusion that nature will speak for itself—if only human beings will quit interrupting. A belief that nature needs no presentation and that presentation is essentially sinister in its intent leaves ecosystems highly susceptible to misunderstanding. Decades ago, Lowenthal and Prince (1965) instructed that people "see their terrain through preferred and accustomed spectacles." As much as our affection for the cultural concept of nature would lead us to believe otherwise, people do not know how to see ecological quality directly. We know how to see ecological quality only through our cultural lenses, and through those lenses, it may or may not look like nature (Nassauer 1992a). Nature has come to be identified with pictorial conventions of the picturesque (Howett 1988), a cultural not ecological concept. More significantly, picturesque conventions have become so integral to landscape perception that we no longer are able to accept their origin in culture (Crandell 1993). Picturesque conventions seem so intrinsic to nature that they are mistaken for ecological quality.

The difference between the scientific concept of ecology and the cultural concept of nature, the difference between function and appearance, demonstrates that applied landscape ecology is essentially a design problem. It is not a straightforward problem of attending to scientific knowledge of ecosystem relationships or an artistic problem of expressing ecological function, but a public landscape problem of addressing cultural expectations that only tangentially relate to ecological function or high art. It requires the translation of ecological patterns into cultural language (Eaton 1990 a,b). It requires placing unfamiliar and frequently undesirable forms inside familiar, attractive packages. It requires designing orderly frames for messy ecosystems.

Some might see culture as an unnecessary barrier between science and popular public attitudes that are increasingly, even cloyingly, green. When the public is highly receptive to doing the right thing for the environment, scientific answers about what is ecologically correct should be sufficient. But in fact social conventions keep the same people who dress in green slogans dressing their homes and cities in homogenous plant communities where enormous species diversity once existed, appreciating robins where once there were warblers, and recycling plastic while depleting aquifers.

Once we begin talking about the landscapes where we live everyday—about specific changes in the way the landscape will look even for the purposes of protecting or improving ecological quality—we encounter fear, anger, rejection. Why? There is a clue in an example from Minneapolis, where a goal had been established to improve water quality in the lakes that form the heart of the public park system and some of the most desirable neighborhoods in the city.

Storm sewers in the watersheds surrounding the lakes emptied directly into the lakes, and the construction of upstream wetlands to act as settling basins for pollutants had been identified as the most efficient means of improving water quality. *Here is the clue:* City council, park board and task force members, and the engineers who were involved in the process that recommended construction referred to the new features as *wetlands*. Citizens who lived near the grassy open spaces that were the proposed construction sites referred to them as *swamps*. The citizens are not self-serving or arbitrary; their perceptions fit within the center of the cultural mainstream. People may care about improving ecological quality but not at the expense of the proper appearance of their own landscapes.

Proper Appearance: Neatness and Ecological Function

It may be time to add a new acronym to the planning lexicon. "Not in my back yard" (NIMBY) resists the siting of controversial land uses. The sentiment expressed here is *not in my yard (NIMY)*. It resists changes in the way my landscape looks because of the way it may reflect on me. Aldo Leopold poetically expressed the powerful social identification of the landowner with the look of the land in 1939:

> The landscape of any farm is the owner's portrait of himself.

We need to recognize that the landscapes of city dwellers' homes, neighborhoods, parks, roadsides, and businesses are public portraits of themselves. The expectation that I represent myself as a citizen in the landscape of my home is etched deeply into popular culture. In the United States it dates at least from the early 19th century (Stilgoe 1988; Pennypacker 1992). Like all highly public speech, the language of landscape does not lend itself to colloquialism. It is adaptable, taking varied forms in different eras, but it is highly attuned to propriety and resistant to fundamental change.

The dominant culture in much of North America reads a neat, orderly landscape as a sign of neighborliness, hard work, and pride. Typically, people want to achieve or know they are expected to achieve this landscape appearance and all that it signifies about themselves. At the same time, a neat, orderly landscape seldom enhances the ecological function of the landscape.

Human Intention and Design

When we conceive of popular perceptions in this way, we think of the role of design differently as well. If I create my landscape in order to communicate with my neighbors and maintain their approval, then the language of form that I believe that my neighbor understands is of paramount importance. *I may like* the idea of living in a landscape that provides wildlife cover, but I am unlikely to change my own yard or advocate that the neighborhood park take on this look if I believe that *people won't like it.*

Human inhabited landscapes operate as ecological systems, but they also operate as communication systems (Lynch 1971), and above all other information, *people seek information about other people* when they experience the landscape. For designers who wish to affect the pervasive landscape pattern that landscape ecology has demonstrated to be fundamental to ecological quality, knowing the everyday language for making and interpreting landscapes will be a necessity.

Special places or preserves may be presented in more arcane scientific or privately expressive language. In the everyday landscape, rather than simply designing to enhance ecological quality or even to express ecological function as form, we must design to *frame ecological function within a recognizable system of form.*

In the everyday landscape of North America, the recognizable system of form typically is characterized by neatness and order. While many observers have associated neatness and order with the human desire to control or dominate the landscape (Tuan 1986; Stein 1993), these characteristics are more validly interpreted as signs of sociable human intention (Nassauer 1988a). Neatness cannot be mistaken for untended nature; it means a person has been in a place and returns frequently. It means a place is under the care of a person.

In settled landscapes, urban or countryside, people expect to see the look of human intention. Where people intend indigenous plant communities or habitats to exist as gardens or preserves, and where the landscape communicates this intention by the way its looks, people are likely to understand that this is "nature" and find it aesthetically pleasing. Where those same plant communities or habitats exist without obvious signs of human intention, they may be mistaken for neglected land or be readily compromised as land awaiting development. Perception of human intention may be the difference between a nature preserve and a dumping ground, or the difference between a wetland and a slough. Designing ecosystems so that people will recognize their beauty and maintain it appropriately may depend upon including design cues of human intention.

Naturalness and Care

While a neat landscape is the unmistakable product of human intention, a natural looking landscape is more likely to be misinterpreted. Nature is a cultural concept that is frequently mistaken as an indication of ecological quality. It has no specific appearance in form and may be as readily applied to a canopied urban plaza (Kaplan 1983) or cultivated field (Nassauer 1979) as to a wilderness.

While naturalness frequently has been described on a continuum from the pristine to "the most humanly degraded end of the ecological scale" (Maser 1990), this intuitively appealing continuum can lead us to significant errors of ecological perception, which have been described earlier (Nassauer 1992a). For example, we might assume that a nature preserve represents the absence of human influence when in fact the existence of intact remnants of indigenous ecosystems depends upon human protection and management. We also might assume that design of landscapes to look natural is a form of deceit about the *real* and destructive effects of human influence. Equating design with deceit leaves no room to acknowledge how design is necessary to represent and maintain ecological function. Finally, we might assume that people know how to see ecological function, that ecosystems speak for themselves. Consequently, we might live in the landscape without knowledge of critical but invisible ecological functions. In fact, invisible ecological function must be actively represented for human experience if human beings are to maintain ecological quality.

The fact that apparent naturalness can lead to such perceptual mistakes about ecological function underscores the power of the cultural concept of naturalness. It we acknowledge the distinction between ecological function and natural appearance, we can begin to critically analyze the cultural language of naturalness and use it as a language to intentionally communicate ecological function.

A large body of landscape perception research suggests some elements of landscape language that communicate naturalness. The elements that are repeated in the conclusions of study after study are vegetation, especially canopy trees, and water (Dearden 1987; Herzog 1989; Kaplan 1983; Knopf 1987; Smardon 1988; Ulrich 1986). Furthermore, this body of research leaves no doubt that people prefer to see landscapes that they perceive as natural.

At the same time, perception of even the most fundamental elements of a natural appearance, vegetation and water, is highly contingent on cultural interpretation. Not all vegetation is equally preferred. For example, a case study of Minnesota owners of rare ecosystems found that owners of oak woodlands tend to appreciate and manage these ecosystems to maintain them, but owners of wetlands or prairies are far less likely to appreciate them. In fact they are likely to change wetlands or prairies in order to "improve" them (Buss 1994). Preference for woodlands is also subject to cultural interpretations. For example, woodlands with dense understory or very dense canopy woodlands may not be attractive (Kaplan 1983; Knopf 1987; Schroeder 1986; Smardon 1988).

Even within the context of appreciating nature, "too much nature" or nature that falls outside cultural expectations is unappealing. In an effort to remake nature to fit cultural expectations, people care for the landscape to the detriment of indigenous ecosystems. Wetlands are mown and planted with exotic species, prairies are planted with trees, and woodlands are mown and cleared of dead wood (Buss 1994).

The naturalness that Americans appreciate today is more closely related to an 18th century concept of the picturesque and the beautiful than it is to the understanding of ecological function (Howett 1988; Robinson 1991; Bonsignore 1992; Crandell 1993). Whether one accounts for the love of a picturesque mix of a neat open ground plane with well-spaced canopy trees on rolling terrain as a consequence of evolution (Appleton 1975; Balling and Falk 1982; Kaplan and Kaplan 1982) or taste (Robinson 1991; Pennypacker 1992; Crandell 1993), the cultural concept of picturesque nature produces a landscape that looks tended, not wild. It enters the recognizable system of landscape form with powerful symbols that work beside neatness to represent human intention.

How we show we are good citizens and good neighbors by the way we care for the landscape to make it look neat or picturesque, safe or inviting, how we use the landscape to express power or wealth—these will establish the framework within which ecosystems are manipulated on a planet dominated by human beings. In an urban or countryside context, people tend to perceive landscapes that exhibit biodiversity as messy, weedy, and unkempt. A central problem in introducing greater biodiversity and heterogeneity to the urban landscape is that these characteristics tend to be mistaken for a lack of care.

Orderly Frames: Cultural Symbols of Neatness and Naturalness

When ecological function is framed by cultural language, it is not obliterated or covered up or compromised. It is set up for viewing, so that people can see it in a new way, much in the same way as Joseph Cornell set up everyday objects in his boxes (Figure 1). Describing Cornell's boxes as descendants of slot machines, Harold Rosenberg (1969) asserted that in comparison with the objects they displayed, the boxes were the artist's "most inclusive symbol," and represented the artist's "means of participating in the common life while holding himself strictly apart from it. (The artist) becomes a member of the crowd by making anonymous use of its games" (p. 78).

Landscape architects need to strike a relationship with vernacular design traditions much like that struck by Cornell: being both "a member of the crowd" and "holding himself strictly apart from it," using its symbols for a different purpose. Cues to human care, expressions of neatness and tended nature, are inclusive symbols by which ecologically rich landscapes can be presented to people and can enter vernacular culture. Working from vernacular culture is necessary to infiltrating everyday acts of landscape change and ultimately achieving radically innovative pervasive landscape structure. This paper summarizes several projects that help to develop the argument for this concept and demonstrate its implications by constructing orderly frames for messy ecosystems.

Human Intention: The Look of Care Farm Fields and Suburban Yards.

We grossly underestimate the power of landscape appearance when we fix our attention on characteristics of scenic landscapes. If we invest only the scenic with aesthetic quality, we construct a very coarse filter that leaves only rare places for our examination and fails to capture the aesthetic experiences and aesthetic conventions that shape the larger landscape matrix. In the United States, most of the countryside, suburbia, and city neighborhoods have been the detritus of this fixation on the scenic. What could possibly make a flat Illinois cornfield without fencerow or farmstead or distant grove beautiful? Farmers see beauty in the straightness of the rows, unin-

Figure 1. Joseph Cornell (American, 1903–1972) *Habitat Group for a Shooting Gallery.* 1943.

Care

Neatness		Stewardship		Naturalness	
Attractive	Unattractive	Attractive	Unattractive	Attractive	Unattractive
Apparent yard care	*Dead or rotten*	*Good conservation*	*Poor conservation*	*Apparent naturalness*	*Too formal*
Fences	Dead or rotten	Conservation	All planted to corn	Development	Too formal
Flowers or shrubs	*Lack of yard care*	Contour plowing	Effluent from	blends in	Too much
Home	No flowers	No erosion	feedlots—poor	Habitat	concrete
Landscaped	No shade	Pasture	water quality	Native vegetation	Too open
Lawn ornaments	Not landscaped	Stripcropping	Erodible land	Natural	Bare
or architectural	Not mown	Terraces	plowed	Trees	Flat
details	*Messy*	Windbreak	No conservation	Wildlife	Monotonous
Trees in rows	Cluttered		practices being		No trees
Big yard	Construction		used		
Big yard	going on		Pastures are		
Clean and neat	Junk		overgrazed		
Clean	Messy		Plowing up the hills		
Neat	*Poor care*		Runoff		
No junk	Abandoned		Slimy looking water		
Put away	Neglected				
Good care	No house on a				
Cared for	farmstead site				
Maintained	*Weedy*				
Well kept	Weedy				
Mown					
Mown					
New					
New					
No weeds					
No weeds					
White					

Figure 2. Content Analysis of Descriptive Terms Organized Under the Concept of Landscape Care.

terrupted by weeds or water, their even green color, and the neatly mown roadside that surrounds the field (Nassauer 1988b). These characteristics constitute a recognizable image of care so powerful that it is a stereotype that has been successfully used to violate its own original meaning—for example as a device for advertising pesticides.

In two projects in which Midwestern farmers described rural landscapes (Nassauer 1988a, 1988b), the look of care was highly associated with landscapes that farmers found attractive. While terms that were used to describe care spanned a range from the neat and tidy aesthetic of "yard care" to the cultural interpretation of "naturalness," all of the terms were summarized under the global concept of care (Figure 2). That terms like "landscaped," as applied to yard care, and "habitat," as applied to naturalness, could be organized under the look of care points to a possible means of resolving perceptual conflicts across this spectrum. Any of these perceived qualities can be the consequence of human intention to care for the land.

In the second rural landscape project (Nassauer 1988b), people who lived in the countryside but were not farmers were also interviewed. Both these people and the farmers tended to use some of the same words and the same global concept, care, to describe what made home landscapes, i.e., yards, attractive as they did to describe what made fields attractive. Not surprisingly, two projects that focused on a suburban landscape matrix dominated by yards returned similar results.

In the first suburban project (Nassauer 1993), 234 residents of a third tier Twin Cities suburb rated video imaging simulations of seven alternative treatments of home landscapes on five dimensions: attractiveness, care, neatness, naturalness, and apparent need for maintenance. The seven alternative treatments of home landscapes demonstrated a range of six increasingly ecologically rich landscapes designed within vernacular expectations (Figure 3): the first treatment was entirely conventional, and the succeeding five framed gardens of indigenous plant communities with cues to human intention. The seventh alternative showed the conventional landscape grown to weeds, untended (Figure 3G). While suburban residents generally preferred the immediately recognizable, conventional landscape treatment (Figure 3A) to all others, they rated the treatment in which half of the mown lawn had been replaced with a garden of plants indigenous to the oak savanna (Figure 3C) almost equally attractive. The weedy lawn (Figure 3G) was rated far less attractive than all other

Figure 3A. Conventional lawn.

Figure 3B. Conventional lawn with native trees and shrubs.

Figure 3C. Replace 50% of the front lawn with prairie garden.

Figure 3D. Replace 75% of the front lawn with prairie grass.

Figure 3E. Replace 50% of the front lawn with oak savanna shrubs.

Figure 3F. Replace 75% of the front lawn with prairie garden and woody shrubs.

Figure 3G. Conventional lawn without mowing or pruning: the weedy lawn.

treatments, including the most ecologically rich design (Figure 3F).

More instructive for designers of human inhabited ecosystems was the association among the five characteristics. In the conventional treatment and the alternative treatments that maintained a strong resemblance to the conventional (Figures 3A-C), care and neatness scores were associated with attractiveness. Naturalness joined that association where half the lawn was replaced by the indigenous garden (3C). The characteristics were associated in the same way for the weedy lawn (3G), but on opposite ends of the scale. The weedy lawn looked unattractive, uncared for, and messy, but it did look natural and as if it required little maintenance. Where more than half the lawn was replaced by the indigenous garden or where the garden was composed entirely of dense indigenous shrubs, the clustering of characteristics was different. Neatness was no longer associated with care and attractiveness. For designers the results suggest that novel suburban landscapes are more likely to be attractive if they look neat and well cared for.

The second suburban landscape project was designed to learn about how people perceived wildlife habitat in their own neighborhoods (Martin 1993). Ethnographic interviews and, later, a complete population survey were conducted in suburban neighborhoods adjacent to the largest urban national wildlife refuge in the United States, the Minnesota River Valley National Wildlife Refuge. Suburban residents said that people who had an attractive yard were neat, cared about the appearance of the neighborhood or about the environment, and took pride in their home or their neighborhood. People who had unattractive yards were believed to not care, to have negative personality traits (to be "different," to have no taste, etc.), or to lack resources to care for their yard. They were also described as not being good neighbors (Martin 1993). In a factor analysis of the 258 terms that suburban residents used to describe attractive and unattractive landscapes in their neighborhoods, four of the eight most powerful factors (cumulative percent of variance = 32.6%) related to care and "landscaping." The other four factors related to attractiveness and naturalness. In these suburban neighborhoods, terms like "park-like, a blend of the natural and unnatural," were associated with naturalness. While people found "bare, severe, or unnatural" landscapes unattractive, they also found landscapes that were "too wild, too countrylike" unattractive. "Wildlife habitat" was a term used by some people to describe what made a landscape attractive and by others to describe what made it unattractive.

Both of the suburban projects support the conclusion that "neatness" labels a landscape as well cared for, and that "naturalness" is defined by cultural expectations. Trees, shrubs, flowers, and grasses look attractive unless there is "too much." Then the immediate cues to care, the presence of human intention, are lost.

Cues to Care

> *. . . Words are never our own . . . language is one strategic part of the total social fact.*
>
> —*Ron Silliman,* quoted in
> Jessica Prinz
> Art Discourse/Discourse in Art

Cues that indicate human intention are cultural symbols that can be used to frame more novel ecosystems in inhabited landscapes. Using cues to care in design is not a means of maintaining traditional landscape forms but rather a means of adapting cultural expectations to recognize new landscape forms that include greater biodiversity. Cues to care make the novel familiar and associate ecosystems that may look messy with unmistakable indications that the landscape is part of a larger intended pattern. The cues may vary from region to region and among ethnic groups, but an underlying principle across cultures and regions is that these cues express care of the landscape. For example, care may be apparent in straight, weed-free rows of corn on a farm in the Midwest, but it may be apparent in an intricate pattern of gourd vines intercropped with corn planted in mounds in dryland farming by the Acoma people in New Mexico. In some places, care will not look neat in the way we might recognize it in a North American suburb. However, cues to care can be observed in the vernacular landscapes of many communities. To identify them, ask yourself the same question that people ask when they are appraising their own yards and neighborhoods: Does it look like they're taking care of it? Then, study the landscape. What makes it look well cared for?

Cues that emerged in the Midwestern studies cited here are:

Mowing. While the omnipresent, large, continuous lawn is not necessary to communicate care, mowing a

Figure 4. The vivid pattern of stripcropping is a cue to care.

strip along human paths (streets, walkways) frames patches of greater biodiversity with clear signs of human intention.

Flowering Plants and Trees. Wetland and prairie plants with small flowers tend to be misunderstood for weeds. If restorations or gardens include an "unnaturally high" proportion of plants with larger, brighter flowers, at least in the first few seasons, people are more likely to find them attractive. Compared with shrubs or grasses, people are more likely to immediately appreciate trees, especially those they themselves can maintain in some way.

Wildlife Feeders and Houses. People widely appreciate songbirds, and while people may not be able to identify the necessary habitat for the birds they enjoy, and they may not find the "brushy" quality of the habitat attractive, they do associate bird houses and feeders with the birds they enjoy. The feeders and houses are structural cues to care for wildlife and habitat.

Bold Patterns. The rural landscape studies described above strongly suggested that the bold, clearly-visible patterns of soil conservation practices like stripcropping (Figure 4), grassed waterways, and terracing were vivid cues to care, even for people who are not farmers or know little about agriculture. These patterns indicate human intention by their crisp edges and landscape scale. Similar patterns can be adapted to urban land uses.

Trimmed Shrubs, Plants in Rows, Linear Planting Designs. At a smaller scale, obvious trimming and pruning of shrubs and linear planting clearly indicate human presence and the intention to care for a landscape.

Fences, Architectural Details, Lawn Ornaments, Painting. These are all structural cues to the care of the adjacent landscape. Where a fence is well-maintained, or especially freshly painted, where nearby buildings are well maintained and painted, where lawn ornaments or architectural details like window boxes or shutters indicate human attention to a place, the landscape nearby is more likely to appear to be well cared for. In the Midwest, the color white used to paint buildings and fences is particularly associated with care.

Foundation Planting. The suburban studies described above indicate that foundation plantings are a nearly unassailable cultural expectation for the home landscape. They should cover the foundation of the house but they should not obscure its windows or doors to fit within the vernacular.

Designs to Frame Messy Ecosystems

Two projects that incorporated cues to care are briefly described below. In the first project, cues to care were used to frame habitat patches that were established as part of the USDA Conservation Reserve Program (CRP). Since 1986, 36.4 million acres of formerly cultivated farmland has been enrolled in the CRP. Despite the enormous habitat and soil conservation benefits that were immediately achieved by the program, people in rural communities were critical of the "weedy, messy" appearance of land in the program (Nassauer 1989 a, b). To address these criticisms, aesthetic conservation to "communicate the appearance of good stewardship" was added to technical guidelines for implementing the CRP after 1990. Cues to care were used to design model landscapes that communicate the appearance of good stewardship for the USDA Soil Conservation Service (Figure 5). Mow strips, bold strip patterns of perennial cover at the recognizable scale of strip cropping, and the use of seed mixes heavily loaded with native forbes all helped to maintain habitat and soil conservation goals, but did so within the familiar language of care for the agricultural landscape.

A second project used cues to care to frame a created wetland in an urban park (Figure 6). The Phalen Wetland Amenity Park is retrofitted on a site that is currently a shopping center (and was a wetland forty years ago) in a stable working class neighborhood of St. Paul, Minnesota. The plan for the park frames the proposed wetland with bold, crisp bands of wet meadow plants that will drift with time but initially will introduce local people to the appearance of a wetland garden. Prairie grasses and forbes pour down an enormous south facing lawn from which people will view the wetland. While the conventional appearance of the lawn establishes that the wetland park is well maintained for people, the prairie grasses filter runoff from lawn and road chemicals before water reaches the wetland.

Conclusions

For new forms of ecologically rich landscapes to be sustained, the forms must be recognized and perpetuated by people in everyday situations, maintaining the landscape and creating their own landscapes. Designing orderly frames is one way of using the vernacular language of landscape to create greater ecological quality. Orderly frames bring novel landscape structures into highly stable social conventions just as Joseph Cornell's boxes allowed the artist to "participate in the common life" and "become a member of the crowd" while using the symbols of the common life for a different purpose (Figure 1) (Rosenberg, 1969). Orderly frames show that design with ecology can be motivated and perpetuated by the most ordinary human desires and habits.

This way of incorporating human nature into a concept of ecological responsibility is very different from requiring human beings to be confronted with ecologically destructive behavior. An "in your face" approach to displaying ecological function would logically extend to exposed septic systems, a landfill in every yard, corporate headquarters sited at chemical dumps, and a sense of ecological justice about natural disasters like flooding and drought. It requires people to accept what they regard as ugly or uncomfortable in exchange for what is attractive and familiar.

Using vernacular language to present unfamiliar ecosystems is also very different from purists' rejection of resource-consuming patches within the larger landscape matrix. Rather it strategically positions small pieces of the old landscape matrix of turf and annual flowers as signposts along an evolving popular landscape aesthetic. It also protects even the most pristine landscapes by clearly labeling them as under human care.

Neither penance nor purism are likely substitutes for the pride and pleasure that people take in familiar landscape patterns. Over the decades of the life of any designed landscape, penance or purism is unlikely to work. What will work is to acknowledge that cultural expectations and human pleasure will continue to be measures of ecological function, at least in everyday experience. Orderly frames are not a means of dominating ecological phenomena for the sake of human pleasure. Orderly frames can be used to construct a widely recognizable cultural framework for ecological quality.

Figure 5: Model conservation landscape designed to communicate the appearance of good stewardship.

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Figure 6: In the Phalen Wetland Park, crisply delineated bands of wet meadow zone plants identify the wetland as the product of human care.

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ORIGINAL ARTICLE

Pixel Art Style Affects Temporal Estimation in Visualized Situations

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Abstract: This study intends to discuss the potential effects of pixel art style on people's perception. In Experiment A, 166 participants were randomly assigned to 2 groups, observed the same dining situation in pixel and vector art style respectively. Results showed that art style did not have a big impact on emotions, however raised a hypothesis that people might tend to believe the situation is in a past era when observing the pixel version. To test that, in Experiment B using 6 different dining situations involving 189 participants, it is found that people in pixel group indeed tend to believe that the situations happen in an earlier period. The effects of pixel art style on imagination remains unclear. This study revealed the potential impact of pixel art style on people's temporal estimation. This phenomenon could be taken advantage of in game design and visual communication design.

Keywords: *Situation, Pixel art style, Temporal estimation*

1. INTRODUCTION

1.1 Background

Previous investigation suggested that visualized situations using simple or detailed sketches was an effective way to represent different product usage situations (e.g. dining situations). The more detailed a visualized situation is illustrated, the stronger and specific emotions can it evoke, whereas a simple version of the situation could avoid providing too much information for people to relate to themselves [1]. It is suggested that a visualized situation should be as simple as possible, with the right level of simplicity that provide just the needed information to the observers. However, no matter how simple a sketch could be drawn, it always has a certain art style. For example, the visualized dining situation in the previous study [1] was drawn by hand on paper, with a relatively realistic art style. There is no discussion made on how the art style of these sketches could make an impact on people's comprehension and emotion.

To answer this question, there are many steps to be made. First of all, the definition of "art style" is important to be clarified. An art style of an illustration could be easily associated with the specific drawing style consistently used by any mangaka (professional comic book illustrator). However, any specific art style that recognized by people is a certain combination of various aspects (e.g. lines, colors, shadows, proportions, etc.). For example, for the aspect of proportions, illustrators could create a cuter art style by simply adjusting the proportion of the human bodies and objects. Therefore, among all these basic aspects of art style, it is essential to study on each one of them separately. One of the most basic aspects is how the dots and lines are drawn. Some art style might use natural lines, while some might take advantage of different pencil strokes. However, there is a more fundamental difference between how the dots and lines are drawn.

A 2D visual illustration is basically either drawn with a vector art style or pixel art style. The simplest difference is, when the lines are continuous, cannot be visually demolished into smaller units, such as dots, it is considered as a vector art style. On the other hand, when the lines are composed by smaller, equal-sized units that are visible to human eyes, it is usually considered as a pixel art style [2]. That being said, pixel art can become vector art, if the pixels are small enough that human eyes cannot recognize them.

Pixel art could be found and traced back to the very early age of human civilization, such as mosaic art from Pompeii [3]. Our ancestors used small, equal-sized tiles to draw arts on floors and walls. Later in the history of fine arts, as an iconic art style, pixel art was also a successor to cubism and constructivism [4]. However, in modern period, it is much more popularized thanks to the boom of computer and digital graphics, and the rise of the game industry. Game designers were "forced" to create a graphics with pixel art, because of the limited resolution of display and low processing power of the computers back in the very early days of video games. Two well-known examples are two of the oldest video games, Space Invaders (1978) and Pac-Man (1980) [5, 6]. In 2000s, with the rapid development of computer graphic technology, game designers were released from the

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restriction of pixel art. Thanks to advanced technology, visual graphics in video games became more and more realistic and rich in presentation. Although astonishing graphics are easily achievable by game developers nowadays, pixel art style did not fade away. In fact, it is getting even more popular in recent years [7]. Pixel art is becoming an artistic choice for game designers [8]. In the Game Award 2018, a video game using pixel art style, called Celeste (2018, [9]), was even nominated as a candidate for the Game of the Year Award, alongside other AAA titles. What is the value in pixel art style?

It is said that there is a difference in the aesthetic values derived from pixel art [3]. As a defining art style of gaming, pixel art not only brings nostalgia, but also attracts people with its minimalist style that fill the blank of imagination [10]. Pixel art games require the players to "fill the gaps" with their imagination, to make sense of it with the little information, and this additional effort is enjoyable, like reading a book compared to watching a movie [8].

1.2 Research Questions

What makes pixel art style special? Is it just a visual style that provides a little diversity to video games and visual communication, or is it more than that? What happens to our comprehension, emotion, and perception on an illustration if we simply pixelate it?

This study intends to investigate the difference between pixel art style and the counterpart: vector art style, using visualized situations, to uncover whether there is a gap between the comprehension, emotion and perception in these 2 art styles.

2. EXPERIMENT A

2.1 Hypotheses and Objectives

Experiment A was carried out to investigate the difference between art styles in a visualized situation, in terms of comprehension and emotion. Moreover, when a visualized situation being used as a visual stimulus, it is important to be perceived as realistic and not difficult for people to picture themselves being in the situation. Therefore, how realistic the situation is and how difficult to picture oneself being in the situation are investigated.

As the most fundamental aspect of art style, pixel and vector art style were chosen as the target of this study. Based on the literature review, pixel art style could evoke a more nostalgic emotion, and trigger imaginations. Here we consider that imagination is important in how realistic a situation feels, and how easy to picture oneself being in the situation. The nostalgic emotion might be stronger for older people, since younger generations might have less experience with pixel art style in the early period of computer graphics. Therefore, age could play a role specifically for pixel art style. If a visualized situation is drawn in pixel art style, it might be easier for people to "fill the blank/gaps", perceive it as a realistic situation, and picture themselves being in the situation. In addition, such effect might be stronger for older people. Since gender's effect on emotion was discovered in previous study [1], the potential impact of gender on these could not be ignored without testing.

the objectives of Experiment A are below:

1. To explore whether any of the emotions evoked by a visualized situation would change between pixel and vector version, and between different gender.
2. To test Hypothesis 1 ($H1$): people perceive a situation as a more realistic one, and can picture themselves in the situation more easily when presented with the pixel version of the situation. Gender also affects these perceptions.
3. To test Hypothesis 2 ($H2$): in a pixel version of the situation, it is easier for older people to perceive it as a realistic one, and picture themselves being in it, whereas there won't be such effect of age in the vector version.

2.2 Method

1) Stimuli:

There is a limited number of studies that have developed a structured list of visualized situations. Given the complexity of situations, categorization methods may vary, and each category may contain vastly different cues, resulting in stimuli that are difficult to compare. Therefore, to address this challenge, it is essential to narrow down the situations by selecting a theme. In a prior study [1], a list of dining situations was developed and tested in a series of experiments, resulting in a more reliable process of generating stimuli. Building on this work, this study has selected dining situations used in the previous study as stimuli. Among the 6 typical dining situations summarized in the previous study [1], one situation was selected because of the strong responses in emotion. Afterwards, since the sketch was already drawn in the vector art style, the pixel art style version was created using Adobe Photoshop. The canvas was adjusted to make sure the general line thickness is 1 pixel but not too much thicker or thinner than the vector version. Finally, two sketches were adjusted to fit the screen in the same size (Figure 1).

Figure 1: Vector version (top) and pixel version (bottom) of the dining situation sketch used in Experiment A

2) Questionnaire:

A questionnaire was created including questions that investigate the comprehension and emotions on a situation. According to the 5 basic cues of a situation ((i) persons, relationships and social interactions; (ii) objects; (iii) events and activities; (iv) locations; (v) time) (e.g. [11-13]), the questions for comprehensions were composed by 5 simple questions [14, 1]. Questions for emotions were based on previous study [15, 1], collecting the major 15 emotional responses of participants on dining situations using 5-point Likert scale. In addition, 2 questions (1. How realistic is this illustration? 2. To what extend are you able to picture yourself in this situation?) with 5-point Likert scale were also included in the questionnaire. The age and gender of the participants were also collected (Table 1).

Table 1: Questionnaire summary of Experiment A

Comprehension questions	Who and what relationship in the situation		
	What objects in the situation		
	What kind of event or affair		
	What period is it happening		
	Where is it happening		
Emotion items	Joy	Coldness	Quietness
	Liveliness	Refreshment	Boresome
	Happiness	Weirdness	Loneliness
	Peacefulness	Freedom	Crampedness
	Warmth	Emptiness	Togetherness
Other	How realistic is this illustration		
	To what extend are you able to picture yourself being in this situation		
	Age		
	Gender		

2.3 Experimental Procedure

The experiment used a between-subject design, participants were randomly assigned to 2 groups, one being the pixel group and the other being the vector group. Firstly, they were asked to observe the dining situation sketch. Afterwards, they were required to answer the questionnaire.

2.4 Analysis

First, responses on comprehension were used to validate participants' basic understandings of the dining situation. Afterwards, ANOVAs (Analysis of Variance) with 2×2 factorial design (IV: "Art style" and "Gender", DV: emotional responses) were conducted to determine whether there were significant effects of art style and gender in each evoked emotion. ANOVAs (IV: "Art style" and "Gender", DV: "realistic" and "picturing oneself") were also conducted to test *H*1. Finally, to explore the relationship between participant's age and how realistic / how easy to picture, independent sample t-test and correlation analysis were conducted respectively on the 2 groups (pixel art and vector art) to test *H*2.

2.5 Results

1) Demographics:

As the perception of pixels can vary depending on the size of the pixels presented on a screen, it was necessary to ensure that participants responded on screens of a similar size during the experiment. To recruit participants, we utilized SurveyMonkey's Audience service, and based on the device type detection function of the service, we found that the vast majority (>95%) were using smartphones. Consequently, we excluded responses from participants using other devices, such as desktop or laptop computers, to ensure that all participants viewed the pixel illustrations on a screen of a similar size. In addition, after discarding questionnaire responses with invalid answers (e.g., random typing in the answer box), 173 total responses remained. In addition, in the comprehension questions, almost all participants correctly understood the basic cues of the situation, answering that the dining situation was about a family, having food together at home. Expect for a few participants thought they were friends and waitress eating in a restaurant. 2 participants thought that a lady was trying to sell a purse in the situation. After excluding these outlier answers, in the end there were 166 total valid responses (69 males & 97 females) that understood the situation correctly. Analyses were done on these 166 responses. The average age of participants was 37.43 years (SD = 12.38), ranged from 20 to 60 years old. For the random assignment, 65 participants were assigned to the pixel group (average age = 37.6, SD = 12.33), including 30 males and 35 females, while 101 participants were assigned to the vector group (average age = 37.32, SD = 12.47), consisting of 39 males and 62 females.

2) ANOVAs on Emotions:

ANOVAs (IV: "Art style" and "Gender", DV: emotional responses) were conducted on all emotion items in Table 1. According to Armstrong's suggestion [16] on when to use Bonferroni correction, since the first objective of the study is an exploratory investigation with no hypothesis, and it was not imperative to avoid a Type I error, Bonferroni corrections should not be applied to these ANOVAs. Among all the results from ANOVAs, there were no significant main effects of art style on emotions. On the other hand, significant main effects of gender were found on emotion items such as "Refreshment" ($F(1, 164) = 5.31, p = .022$), "Quietness" ($F(1, 164) = 5.07, p = .026$), "Loneliness" ($F(1, 164) = 5.73, p = .018$), and "Crampedness" ($F(1, 164) = 4.49, p = .029$). Several significant interactions were also found on "Happiness" ($F(1, 164) = 3.92, p = .049$), "Refreshment" ($F(1, 164) = 6.24, p = .013$), "Freedom" ($F(1, 164) = 4.52, p = .035$), and "Togetherness" ($F(1, 164) = 4.44, p = .037$).

3) ANOVAs on "How Realistic" and "How Easy to Picture":

ANOVAs (IV: "Art style" and "Gender", DV: "Realistic" and "Picturing oneself") were conducted to test *H*1. No significant main effect of either art style or gender was found. No interaction between them was found, either.

4) Independent sample t-tests and Correlation Analyses on "How Realistic" and "How Easy to Picture":

Independent sample t-tests and correlation analyses were carried out to test *H*2. In conducting the t-test, the age range of the participants, spanning from 20 to 60 years old, was utilized to categorize participants into two distinct groups: older (age >= 40) and younger (age < 40). This was achieved by setting a threshold age of 40 years to separate relatively older and younger participants. In the pixel group, a between-subjects t-test was conducted to compare the means of older group ($M = 3.16, SD = 0.85$) and younger group ($M = 2.45, SD = 1.31$) on the variable "Picturing oneself". The results indicated a significant difference between the two groups, $t = 2.87(61), p = .006$, with older group scoring higher on average than younger group. Such significant result was not found in the t-test in the vector group (Figure 2). There was also a low positive correlation between "Age" and "Picturing oneself" ($r = .30, p = .014$), indicating that older participants tended to be able to picture themselves in the situation easier than younger participants, only found in the pixel group.

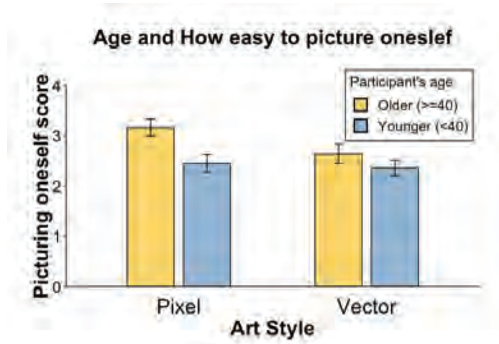

Figure 2: Bar plot showing the differences among older and younger participants in pixel and vector groups, on the evaluation of "How Easy to Picture oneself"
The error bars show standard errors.

2.6 Discussion

First of all, results supported previous study [1], showing that gender plays a big role in evoking emotions in a visualized dining situation. Compared to gender, there was no significant main effect of art style on any of the emotional responses on the dining situation. This suggests that simply by changing the art style of a visualized dining situation from vector to pixel might not provide much effect on the emotions that related to the dining situation.

When applying a visualized dining situation in various scenarios, it is considered that how realistic the situation feels and how easy to picture oneself being in it are very important. Results showed no difference among the two art styles and two genders, indicating that no matter pixel or vector, male or female, the level of "how realistic it feels" and "how easy to picture oneself being in it" might not change. Changing the art style from vector to pixel wouldn't make people feel more realistic on the situation, wouldn't make it easier for people to picture themselves being in the situation. *H*1 was not supported. Although it is being said that pixel art style could invite more imagination to "fill the gaps/blank" [8, 10], simply by pixelating the lines might not work. It could be more due to the simplicity of the visual stimuli, since the difference between pixel games and other games are usually not just the art style, but also the simplicity regarding many visual aspects.

When taking the age of participants into consideration, it is found that when observing the pixel version of the dining situation, it is easier for older people to picture themselves being in it, and such result was not found for the vector version. This partially supports *H*2, saying that the pixel art style indeed makes older people relate themselves more. However, since this effect of pixel art style was not found for "Realistic", it cannot prove that older people actually can imagine more because of their experience with pixel art compared to younger generation. No matter how old the person is, he/she sees no difference on the level of how realistic it is between pixel and vector version of the dining situation. In general, it is assumed that if individuals can easily imagine themselves in a situation, it may appear more realistic to them. Therefore, a new question is: why can older people picture themselves more easily in the dining situation, but not necessarily feel it more realistic than younger generation when observing a pixel version of the dining situation?

To answer this question and understand this difference between the perception of older people and younger people on the pixel art style, additional analyses were conducted. To ensure the validity of the responses, screening was performed, and 'bad' answers were removed based on whether the participant demonstrated an understanding of the basic cues of the situation. Comprehension questions in Table 1 were used as a criterion for validity, with responses indicating an understanding of the relationships between individuals and objects considered valid. For example, in the first question "Who and what relationship?", responses with the answer of "family" or "relatives" were considered valid, however responses with the answer of "customers and sales associate" were eliminated. In general, all responses demonstrated mutual understanding of the situation among the 5 questions, except for the fourth question: "What period is it?". The ambiguity of this question caused participants understood the question in different ways. Among all 166 responses, 53 responses answered the questions with the period of different eras, such as either past era (it looks like in the 70s/80s, etc.) or modern era (it looks like modern time, etc.), whereas 113 responses answered the question with the different period of time of a day, such as dinner time, evening, morning, etc. Since the dining situation was not illustrated with any intention to represent a specific time (although "dinner" seems more appropriate, answers with "morning" were not considered incorrect), all these answers were considered valid and were not eliminated. However, in order to understand how people perceive pixel and vector versions of the dining situation differently, the first group of responses (53) with the answer of either past era or modern era could be considered as the temporal estimation of the situation (summarized in Table 2). As can be seen by the frequencies cross tabulated in Table 2, there is a significant relationship between art style and perceived era, $X^2(1, N = 53) = 7.67$, $p = .006$. Participants in the pixel art group were more likely to perceive it happening in a past era than were in the vector group. This might be one of the main reasons why older people were able to relate

Table 2: Art style and temporal estimation in Experiment A: numbers of participants in each group of art style, estimated different period of the situation, past era (70s, 80s, etc.) or modern era (modern time, today, etc.)

Art style	Past era	Modern era
Pixel	14	9
Vector	7	23

to themselves, imagine themselves being in the situation, without necessarily feeling more realistic about it. Since the pixel version of the situation actually looked "older", the older participants could associate themselves to it more, because they have been living in the past era compared to younger ones. Younger people could also think the situation is a realistic one, it is just more difficult for them to picture themselves being in the situation because it looked like something happening in the past era when they were not born yet. It could be clearly seen in Table 2 that the dining situation itself is not "old" at all, since participants in the vector art group believed that it was more likely happening in a modern era. It is just the art style of pixel made it looked "older". This brings up a hypothesis that pixel art style might affect our temporal estimation of a visualized situation.

3. EXPERIMENT B

3.1 Hypotheses and Objectives

Based on the findings in Experiment A, there is a tendency that pixel art style might affect temporal estimation, lead to perceiving the time of the event being in an earlier period. Since this was only observed by a follow-up chi-square analysis on counting answers in the free comments, a more well-planned experiment using more visualized situations was needed to validate this hypothesis. On the other hand, it is unclear whether gender could also affect temporal estimation, therefore gender should also be considered as a factor. In addition, since the questions used in Experiment A did not discover any connection between pixel art style and imagination, Experiment B tried to explore whether pixel art style could trigger more imagination.

the objectives of Experiment B are below:

1. To test Hypothesis 3 (*H*3): when dining situations were illustrated in pixel art style, people would estimate it being in an earlier period, compared with vector art style. Gender might also affect this phenomenon.
2. To find out whether a dining situation in pixel art style would trigger more imagination.

3.2 Method

1) Stimuli:

Following the procedure of creating the dining situation sketch in Experiment A, a total number of 6 visualized situations were pixelated (Figure 3).

2) Questionnaire:

The questionnaire contains 5 questions. The first question asked about participant's temporal estimation of the dining situation. Participants could select the most likely option from 9 different decades. The second question allows participants write down free comments, list up anything that came into their mind when they were presented with the visualized situation (Table 3).

Questions 3, 4, and 5 were designed to inquire about participants' preferences regarding video games, pixel art style in video games, and pixel art style in general, in order to investigate whether there is a relationship between the level of preference for pixel art or video games and temporal estimation in the pixel group.

Figure 3: Vector version (first row, left to right, situation No.1–3, second row, left to right, situation No.4–6) and pixel version (first row, left to right, situation No.1–3, second row, left to right, situation No.4–6)

Table 3: Questionnaire summary of Experiment B

Questions	Answer (options)
(1) What is the most likely time period does this situation look like?	1950s, 1960s, 1970s, 1980s, 1990s, 2000s, 2010s, 2020s, 2030s
(2) Please list up the words came into your mind, or any thing (concept, emotion, event, etc.) you can imagine based on this illustration, as many as possible.	Free comments.
(3) How much do you like video games?	5-point Likert scale
(4) How much do you like pixel art style in video games?	5-point Likert scale
(5) How much do you like pixel art style in general?	5-point Likert scale

3.3 Experimental Procedure

Experiment B also used a between-subject design, participants were randomly assigned to 2 groups, one being the pixel group and the other being the vector group. In each group, participants observed each one of the 6 dining situations, and answered the first 2 questions, until completing all 6 dining situations. Questions (3), (4), (5) were asked only once at the end of the experiment.

3.4 Analysis

Participants' selection in the first question were converted into a 9-point Likert scale. The linear relationship between temporal estimation and age was confirmed, therefore age was considered as a covariate that should be controlled in the analysis. Factorial ANCOVA (Analysis of Covariance) was conducted, using art style (pixel & vector) and gender (male & female) as independent variables, age as covariate, and temporal estimation as dependent variable, to see if there is a significant difference between vector version and pixel version, male and female, on the estimated time period of the situations. The second question was analyzed using thematic analysis [17]. All participants' free comments were reviewed by the researcher. Specific themes representing different levels of imagination would be summarized. Afterwards, the difference between pixel group and vector group in the levels of imagination would be discussed using basic statistics of the themes.

3.5 Results

1) Demographics:

After excluding answers using desktop or laptop devices, and discarding invalid and incomplete questionnaire responses, valid responses ($n = 189$) were used in the analysis. Pixel group ($n = 94$, 50 females) has an average age of 46.03 ($SD = 17.40$), and vector group ($n = 95$, 52 females) has an average age of 43.67 ($SD = 17.97$). An independent samples t-test was conducted to compare the mean age of the two groups, and the test statistic was $t(198) = .94$, $p = .35$, showing that there was no significant difference between the age of the participants in pixel group and vector group.

2) Temporal estimation:

First of all, the scatter plot in Figure 4 shows an example of the linear relationship between age and temporal

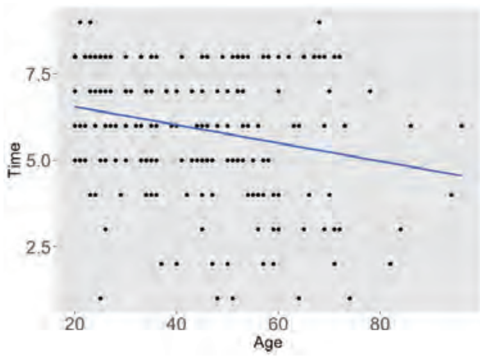

Figure 4: Linear relationship between "Age" and "Time" (temporal estimation) in situation No.1 in Experiment B

Table 4: Mean scores of temporal estimations for each condition

Situation No.		Pixel Male	Pixel Female	Vector Male	Vector Female
1	M	6.41	5.42	5.93	5.85
	SD	1.62	2.23	1.82	2.01
2	M	5.70	3.90	5.77	5.10
	SD	2.12	2.37	2.01	2.35
3	M	6.14	6.06	6.81	6.58
	SD	1.89	1.98	1.61	1.79
4	M	5.27	5.22	6.30	6.44
	SD	2.07	2.01	1.74	1.51
5	M	4.98	4.74	5.44	5.44
	SD	1.89	2.11	1.87	2.06
6	M	5.34	5.94	6.91	6.19
	SD	2.03	1.72	1.25	1.72

The scores were converted from 9-point Likert scale, with 1 being 1950s, and 9 being 2030s. The higher the score is, the later the period is estimated by the participants.

estimation in situation No.1. Similarly, linear relationship was found in other situations, too. As a continuous variable, age could vary along with temporal estimation, which was controlled as a covariate. A two-way ANCOVA was performed to examine the effects of art style and gender on temporal estimation, after controlling for age.

Table 4 shows the means and standard deviation of the scores of temporal estimation for each condition in all situations. The scores were converted from 9-point Likert scale, with 1 being 1950s, and 9 being 2030s. Therefore, a mean score of 6 means that the participants in that group estimated the situation happening around 2000s. The higher the score is, the later the period is estimated by the participants. The lowest score is observed in female participants in the pixel group. When they were rating situation No.2, the average score was 3.90 (later in the 1970s). The highest score is in male participants in the vector group, showing a mean score of 6.91 (later in the 2000s).

Table 5: Results of ANCOVA on temporal estimation

Situation No.	Art style		Gender		Art style : Gender	
	F	p	F	p	F	p
1	.05	.83	3.37	.07	1.51	.22
2	3.57	.06	14.30	<.01 **	2.02	.16
3	4.31	.04 *	.29	.59	.33	.56
4	17.64	<.01 **	.03	.87	.12	.73
5	3.40	.07	.11	.74	<.01	.99
6	11.14	<.01 **	.04	.85	8.55	<.01 **

Table 5 shows the result of ANCOVA analysis. There was no significant effects or interaction in situation No.1 and No.5. In situation No.2, there was a significant main effect of gender on temporal estimation, $F(1, 184) = 14.30$, $p < .001$. Pairwise comparison showed that females significantly estimated the time period earlier than male ($\Delta = 3.71$, $p < .001$). In situation No.3, there was a significant main effect of art style on temporal estimation, $F(1, 184) = 4.31$, $p = .039$. Pairwise comparison showed that participants in pixel group significantly estimated the time period earlier than those in vector group ($\Delta = 2.08$, $p = .039$). In situation No.4, there was a significant main effect of art style on temporal estimation, $F(1, 184) = 17.64$, $p < .001$. Pairwise comparison showed that participants in pixel group significantly estimated the time period earlier than those in vector group ($\Delta = 4.22$, $p < .001$). In situation No.6, there was a significant main effect of art style on temporal estimation, $F(1, 184) = 11.14$, $p = .001$. Pairwise comparison showed that participants in pixel group significantly estimated the time period earlier than those in vector group ($\Delta = 3.28$, $p = .001$). In addition, there was a statistically significant interaction between art style and gender on temporal estimation for situation No.6, whilst controlling for age, $F(1, 184) = 8.55$, $p = .004$. The simple main effect of art style was statistically significant in the males, $F(1, 84) = 18.8$, $p < .001$, but not in the females $(1, 99) = .07$, $p = .786$. Pairwise comparison shows that male participants in pixel group significantly estimated the time period earlier than male participants in vector group ($\Delta = 4.41$, $p < .001$). In addition, in situation No.2 and No.5, the main effect of art style did not show a statistically significant result, however, both of them showed a tendency of pixel art style being estimated earlier than vector art style, close to a significant level (situation No.2: $F(1, 184) = 3.57$, $p = .060$, situation No.5: $F(1, 184) = 3.40$, $p = .067$). In summary, 5 of the 6 situations yielded results showing that participants in

Table 6: Examples in the free comment answers in Question (2) of Experiment B

Situation	Answer examples	
1	Frequent words	Date, love, romance, anniversary, toast, beautiful, couple, wife, celebration, etc.
	Imaginative answer example	"My wife and I toasting our commitment."
2	Frequent words	Family, tradition, together, holiday, happy, delicious, laughter, etc.
	Imaginative answer example	"Before my children left home when children & their family come to visit holiday seasons."
3	Frequent words	Couch, food, calm, lonely, drinking, alcohol, single, etc.
	Imaginative answer example	"Eating alone in quarantine. Covid, loneliness, fear, anxiety, wishing things could be different."
4	Frequent words	Breakfast, newspaper, rude, coffee, disconnected, brunch, morning, work, etc.
	Imaginative answer example	"Father and son, son with cellphone, eating, talking at same time to get dad's attention but not pushing it."
5	Frequent words	Picnic, family, childhood, sunshine, outside, peaceful, kids, nature, etc.
	Imaginative answer example	"Picnic, happy, loving family, marriage, kids, this picture makes me think of the future and the possibilities of it."
6	Frequent words	Friends, joy, barbeque, family, teens, Asian food, group, fun, etc.
	Imaginative answer example	"Classic Chinese hot pot! I love it, one of my favorites. I would still go if we had one here."

the pixel group significantly estimated the time period of the situation earlier than the vector group, with 3 being statistically significant and 2 being close to significant. Gender's main effect was found in one of the situations and the interaction between gender and art style was found in another one of the situations. Therefore, null hypotheses were rejected, *H*3 was partially accepted.

3) Imagination:

Table 6 presents a selection of typical responses to Question (2). The column labeled "Frequent Words" displays the words that appeared most frequently in the answers. In contrast, the column labeled "Imaginative Answer Examples" provides examples of responses that were particularly distinctive and imaginative, and thus may be considered as indicative of a higher level of imaginative thinking.

In thematic analysis, it was observed that participant's free comments on the 2nd question could be categorized using 7 themes, shown in Table 7. Each theme represents a different level in imagination. The 1st theme was named "1_Basic", it was recorded when the answer includes descriptions about the basic cues in the situation. For example, in situation No.1, if a participant's answer included descriptions like "a couple is having dinner", it is considered a very basic and obvious statement on the basic cues, indicating the persons and event in the situation. The imagination level is considered lowest in this theme. The 2nd theme was named "2_Adjective". It was recorded when adjectives that modify the basic cues were seen in the comments. For example, in situation No.1, a participant used "formal" to describe the "dress" seen in the illustration, it was counted under the theme of "2_Adjective". These adjectives do not express much emotions or imagination. The 3rd theme was named 3_Emotional to record any emotional expressions. For instance, "romantic", "happy" were counted as emotions in situation No.1. The 4th theme is 4_Concept. When participants associated any abstract concept, like "marriage", "commitment" from situation No.1, they were counted as concept. The 5th theme was named "5_Storytelling". This is when participants started adding their own estimation or imagination to the situation. For instance, in situation No.1, although it was not indicated, some participants wrote "they are having a first date". The 6th theme is "6_Personal". It was recorded when the comment included participant's personal past experience that being recalled. The last theme was named "7_Imaginary", it was counted when participants started describing their imaginary objects or persons that do not even exist in the illustration.

Table 7: Coding in the thematic analysis for Question (2) of Experiment B

Theme	Explanation (examples in situation 1)
1_Basic	Words that describe situation's basic cues, e.g., "A couple is having dinner", etc.
2_Adjective	Words that modify the basic cues, e.g., "formal dress", "handsome", etc.
3_Emotional	Words that describe the evoked emotions of the participants, e.g., "I feel romantic", "happy", etc.
4_Concept	Words that describe an abstract concept associated from the situation, e.g., "marriage", "commitment", etc.
5_Storytelling	Participants started telling stories containing information beyond the basic cues, e.g., "they are having a first date", etc.
6_Personal	Participants started describing their personal experience, e.g., "when I was dating my wife", etc.
7_Imaginary	Participants started purely imagining objects that do not exist in the illustration, e.g., "candle", "children", "sparkle", etc.

Table 8: Summary of the results of thematic analysis

No.		1B	2A	3E	4C	5S	6P	7I
1	Pixel	52	18	29	26	7	9	1
	Vector	56	19	29	29	3	9	7
2	Pixel	66	12	18	18	6	7	5
	Vector	81	11	22	34	6	7	5
3	Pixel	55	11	17	13	6	4	33
	Vector	49	7	33	17	20	8	7
4	Pixel	60	9	13	17	4	1	3
	Vector	49	23	13	19	5	2	5
5	Pixel	73	23	14	10	2	7	7
	Vector	73	16	19	11	1	7	6
6	Pixel	69	22	17	10	2	3	1
	Vector	75	17	10	14	2	9	1

The numbers represent the frequency of each theme appeared in the answers in pixel and vector group in each situation.
"No." on the left column means the situation No.
The header from "1B" to "7I" represent the 7 themes.

The results of thematic analysis for each dining situation are summarized in Table 8. The total responses for pixel and vector group are 94 and 95 respectively, the numbers in Table 8 represents the frequency of each theme in the responses. In general, "1_Basic" was found in the majority of participants' comments, with approximately 50%−80% (minimum 49 responses to maximum 81 responses among 90+ total participants) participants mentioned in the comments. Following is "2_Adjective", "3_Emotional" and "4_Concept", with between 10% to 30% (minimum 9 responses to maximum 34 responses among 90+ total participants) participants mentioned. In the end, "5_Storytelling", "6_Personal" and "7_Imaginary" were barely found, less than 10% (basically single digit responses) in all situations, except for situation No.3, with "5_Storytelling" being found in more than 20% (20 responses in 95 total participants) participant's comments in the vector group, and "7_Imaginary" being found in more than 30% (33 responses among 94 total participants) participant's comments in the pixel group.

4) Correlation between temporal estimation and preferences on pixel art / video games:

Table 9 displays the results of the correlation analysis conducted to examine the potential relationship between temporal estimation and participants' preferences for video games and pixel art style (Questions 3, 4, and 5 in Experiment B). The results of the analysis indicate that there was no significant correlation found between the level of preference for pixel art style in video games and the accuracy of temporal estimation.

Table 9: Summary of the correlation analysis between temporal estimation and preferences for video games and pixel art style in pixel group

Variable A	Variable B	Situation No.	Correlations between Variable A & B	
			r	p
Temporal estimation	Preference on video games	1	−.05	.64
		2	.08	.44
		3	.08	.44
		4	−.04	.66
		5	.04	.73
		6	−.14	.16
Temporal estimation	Preference on pixel art in video games	1	.05	.63
		2	.10	.30
		3	.07	.46
		4	−.02	.83
		5	.10	.30
		6	<.01	1
Temporal estimation	Preference on pixel art in general	1	−.05	.62
		2	.12	.23
		3	.02	.81
		4	−.05	.63
		5	.05	.65
		6	−.11	.27

3.6 Discussion

*H*3 was partially supported, showing that pixel art style affected participant's temporal estimation, in a way of making the visualized situation seem to be happening in an earlier time period. This could be called "the pixel art style effect". The significant differences were found in 3 of the 6 situations, and 2 situations with tendencies that were very close to significant. Among these 5 of the 6 illustrations, all of them showed that the pixel version of the situation looked earlier in time period, making it a strong case for "the pixel art style effect". For gender effect, only situation No.2 appeared to be earlier in time period for females than males, regardless of the art style. Finally, in situation No.6, there was an interaction that the "pixel art style effect" was stronger in males than females.

The only exception for "the pixel art style effect" was situation No.1, "dinner dating with partner". The characteristics of situation No.1 might be very time-specific, strongly affecting participant's temporal estimation of the situation regardless of the art style. On the other hand, the rest of the other dining situations do not have the time-specific feature, therefore the art style could play a bigger role and affect their temporal estimation strongly enough to show a significant difference. However, the reason why this "dinner dating with partner" situation is time specific is still just a hypothesis that needs to be further explored.

Experiment B successfully discovered the phenomenon that pixel art style could affect people's temporal estimation on a visualized situation. In the follow-up correlation analysis on the relationship between temporal estimation and the preferences on video games/pixel art style, no significant correlation was found between the preference on pixel art style (video games) and the estimation of time period. The general impression of "retro" and "nostalgia" on pixel art style might played a role in affecting participants' cognition subconsciously. However, there was no evidence in this experiment to prove this point. Pixel art style's abstract, blurry visual might be a key factor that influence our perception. Further investigations are needed to explore the actual reasons behind this phenomenon.

For imagination, there was no noticeable findings to prove that pixel art style could trigger more imagination. Among the themes in thematic analysis, the last 3 themes are considered comments with higher level of imagination. In situation No.3 (a man sitting on the couch drinking alone), there were obviously more people in the pixel group described more imaginary items, while there were slightly more people in the vector group trying to tell a story. Since this is the only dining situation with only 1 person in it, it might involve participant's imagination in a different way. Other than this finding, there was not enough observations to provide any conclusion.

4. CONCLUSION

It is widely known in the game industry that pixel art style would make a game look more "retro" and "nostalgic". However, these feelings are not clearly explored and defined. In general, a retro game usually means it is made in the past era, it is an "old" game. It does not necessarily mean we also think what is happening in the game is also in a past era. However, in this study, it is found that simply by pixelating the dots and lines of a dining situation sketch, the pixel art style could affect temporal estimation, trick people to believe that the situation is happening in an earlier time period. This might lead to older people feeling easier to picture themselves being in the situation. Designers and illustrators should take advantage of this phenomenon in game design and media graphic design. Researchers are recommended to conduct future studies to explore this phenomenon.

The "retro" characteristic of pixel art style does not simply mean that the content looks like being made in a past era, it might also influence what we comprehend on the "story" of the content. However, the mechanism behind this effect still remains unclear. Situations with stronger time-specific contents might be immune to this effect.

There is no clear evidence that pixel art style could stimulate more imagination and "fill the gaps/blank" compared to vector art style. The simplicity of the visuals might be a more important factor. A situation with only 1 person in it might connect to our imagination in a different way and has a potential to be affected by art style. This needs to be further discussed in experiment using pixel art style and vector art style with different level of simplicity, and the number of persons in a situation is an interesting topic.

5. LIMITATIONS

One limitation of this study is that it focused solely on the dining situation. This was due in part to the fact that dining situations have been relatively well-studied in the past and there are established visual representations of this context that can be used in experiments. However, this limitation also means that the findings may not generalize to other social situations that have not been as extensively studied. On the other hand, regarding studies on pixel art style, visualized situation is only one of the many approaches. It may be valuable to expand the study of pixel art style in video game design, poster design, commercial design, and other real-world applications.

Another limitation of the study is that the levels of imagination were created solely based on observing the raw data obtained from Experiment B, which did not yield effective results. Therefore, it is necessary to develop better methods to comprehend the levels of imagination in a more structured manner.

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NOTES

The experiments in this study were conducted under the approval of the ethic committee at the author's affiliated institute. Experiment A was presented at the International Conference on Kansei Engineering and Emotion Research 2022 (KEER2022), and published in the Proceedings of the 9th International Conference on Kansei Engineering and Emotion Research [18].

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Thinking in systems – a primer

Petra Wächter

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Thinking in systems – a primer, by Donella H. Meadows and edited by Diana Wright, London, Earthscan, 2009, xiii + 218 pp., index, £60.00 (hardback), ISBN 9781844077250, £14.99 (paperback), ISBN 9781844077267

It is nearly 20 years since Donella H. Meadows completed a draft version of the present book in 1993. Before her sudden death in 2001 she was not able to finalise the book. Fortunately, Diana Wright decided that the manuscript should be released and she edited the text and restructured the artwork for publication in 2009. Although the book is not new, it remains important. Meadows can be regarded as an outstanding expert on systems, modelling, and communicating system dynamics. She was lead author of one of the most influential books on sustainable development, *Limits to Growth*.

Her desire to bring her knowledge of systems to the public was the motivation for writing the book *Thinking in Systems*. To understand the book it is not necessary to have any experience of systems thinking. The introductory character of the book should make it attractive not only for students but also to a broad interested public, including policy-makers, business people and other decisions-makers, and to everyone who wants to know more about how systems work. It is written in a lively style, easy to follow, and with various examples to help explain the issues under discussion. Its accessibility encourages the reader to think that it is all very obvious with very basic concepts but later you begin to realise the complexity of the issues and the significance of a systems approach. This is the key strength of the book: explaining very profound systems dynamics and models in easy to understand language with helpful figures and tables to illustrate ideas.

Meadows starts by picturing what a system is – a stock with inflows and outflows that affect its stability and all of which are further affected by feedback loops and delays. We learn about system structures, systems behaviour, and about simple systems principles. The introductory section is followed by discussion of system dynamic models, exploring possible futures and analysing factors that drive systems. Meadows emphasises that model utility depends not on whether its driving scenarios are realistic but on whether it responds with a realistic pattern of behaviour. The reader learns about constraints on systems, resilience, self-organisation and hierarchy, and about the source of systems surprises. The book provides many interesting insights, for example, at any given time, the input that is most important to a system is the one that is most limiting (p. 101). Through systems surprises we are confronted with system traps, which concern, for example, policy resistance or the famous tragedy of the commons. Meadows' solution to the tragedy of the commons lies in privatising the resource so that its owners are directly, economically affected by its abuse. She also considers the most effective places to intervene in a system, discussing the roles of system constants and parameters, such as subsidies or taxes, the role of paradigms, or the mind-set out of which a system arises, and the role of transcending paradigms. At the end of the book, Meadows gives us some guidelines for living in a world of systems and she finishes with the most important rule, not to erode the goal of 'goodness'.

I would recommend this book to anyone who worries about the world and its development. It provides an excellent introduction to thinking in systems and the significance of systems thinking for the future of the planet.

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World Bank Group interactions with environmentalists: changing international organisation identities, by Susan Park, Issues in Environmental Politics series, Manchester, Manchester University Press, 2010, xx + 256 pp., index, $90 (hardback), ISBN 9780719079474 and 0719079470

The focus of the book is on the dynamic interactions of the World Bank Group (WBG) with environmentalists over several decades. The pressures applied by transnational environmental advocacy networks (TEANs) resulted in the internalising of new norms by international organisations (IOs) and gradually moved the WBG toward more environmentally friendly and socially sensitive policies and practices in developing countries. Using coercive measures as well as persuasion and negotiation, the TEANs fostered the reconstitution of the IOs' neoliberal economic identity towards internalising norms consistent with the concepts of sustainable development. Therefore, the TEANs were pressuring the WBG to become sustainable development lenders, investors and political insurers. Susan Park analyses why, how and to what extent sustainable development norms have become diffused into the projects, policies and institutions of the WBG, and to what extent their identity has changed.

The book sheds light on the complex interactions between the TEANs, states and the IOs from a non-state-centric perspective. Park presents a phenomenological explanation of the processes and mechanisms of the internationalisation of new norms by the WBG. She demonstrates that the IOs were influenced not only by state actors, but to a large extent their behaviour was shaped and determined by non-state actors, such as TEANs and other non-governmental organisations, who have much less financial power, but enjoy a legitimacy and authority recognised by wide public audiences. By challenging the IOs directly, and indirectly through the member states, TEANs were able to shape world politics and diffuse new norms into both financial institutions and member states.

Park analyses the phenomenon of the greening of the WBG's institutions from both rationalist and constructivist perspectives. From the constructivist

Case Studies

Adventure

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.run adven


WELCOME TO ADVENTURE!!  WOULD YOU LIKE INSTRUCTIONS?

yes

SOMEWHERE NEARBY IS COLOSSAL CAVE, WHERE OTHERS HAVE FOUND FORTUNES IN
TREASURE AND GOLD, THOUGH IT IS RUMORED THAT SOME WHO ENTER ARE NEVER
SEEN AGAIN.  MAGIC IS SAID TO WORK IN THE CAVE.  I WILL BE YOUR EYES
AND HANDS.  DIRECT ME WITH COMMANDS OF 1 OR 2 WORDS.  I SHOULD WARN
YOU THAT I LOOK AT ONLY THE FIRST FIVE LETTERS OF EACH WORD, SO YOU'LL
HAVE TO ENTER "NORTHEAST" AS "NE" TO DISTINGUISH IT FROM "NORTH".
(SHOULD YOU GET STUCK, TYPE "HELP" FOR SOME GENERAL HINTS.  FOR INFOR-
MATION ON HOW TO END YOUR ADVENTURE, ETC., TYPE "INFO".)
                              - - -
THIS PROGRAM WAS ORIGINALLY DEVELOPED BY WILLIE CROWTHER.  MOST OF THE
FEATURES OF THE CURRENT PROGRAM WERE ADDED BY DON WOODS (DON @ SU-AI).
CONTACT DON IF YOU HAVE ANY QUESTIONS, COMMENTS, ETC.

YOU ARE STANDING AT THE END OF A ROAD BEFORE A SMALL BRICK BUILDING.
AROUND YOU IS A FOREST.  A SMALL STREAM FLOWS OUT OF THE BUILDING AND
DOWN A GULLY.

east

YOU ARE INSIDE A BUILDING, A WELL HOUSE FOR A LARGE SPRING.

THERE ARE SOME KEYS ON THE GROUND HERE.

THERE IS A SHINY BRASS LAMP NEARBY.

THERE IS FOOD HERE.
```

Figure 5 - https://en.wikipedia.org/wiki/Colossal_Cave_Adventure

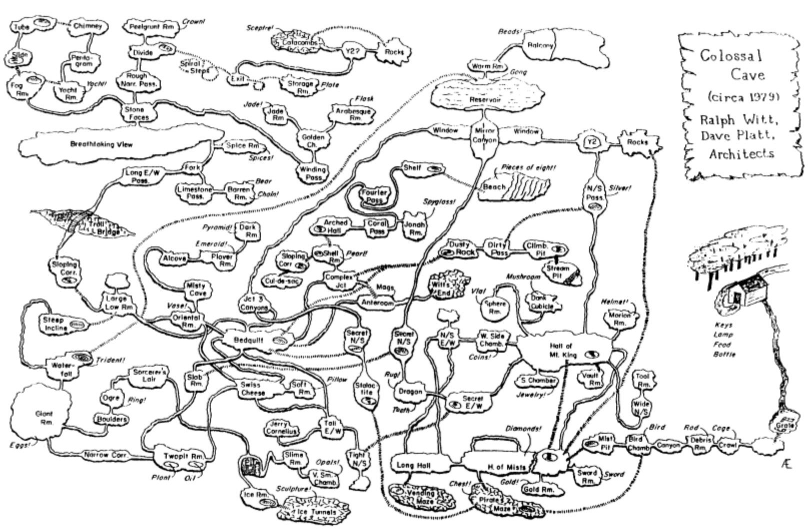
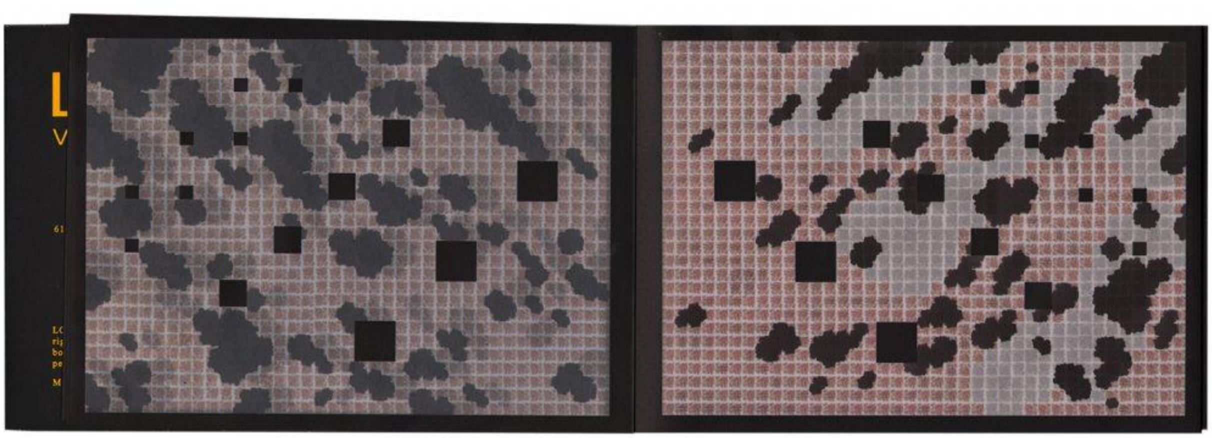


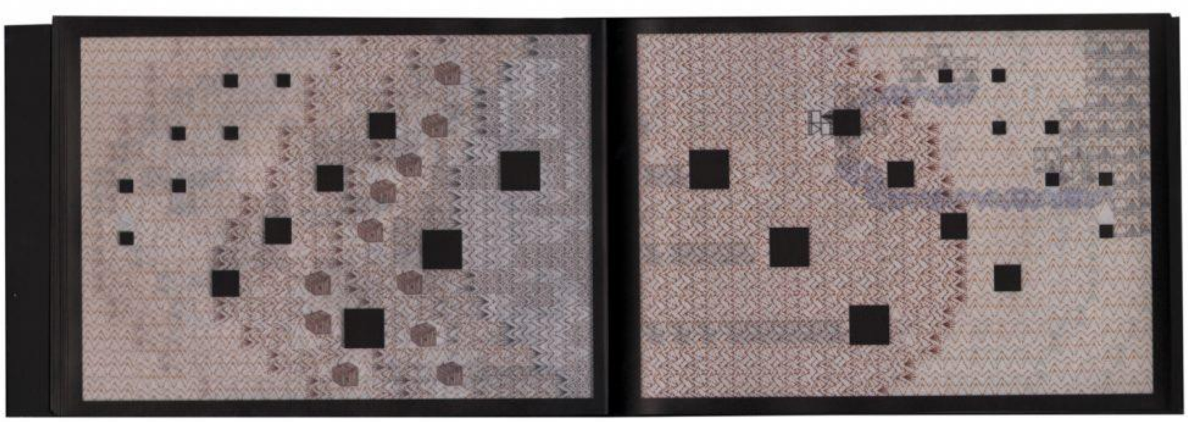
Figure 6 - https://www.dragonsfoot.org/forums/viewtopic.php?t=25474

Colossal Cave Adventure, also known as *Adventure,* is a text-based cave exploration game created by Will Crowther in 1976-1977. It is one of the earliest forms of interactive fiction and computer games, and accurately portrays a cave system described through text. The player interacts by typing commands to move throughout the cave and solve puzzles.

Adventure relies on no graphical representation other than text, encouraging players to form the complexity of the cave in their imagination. This is a method of abstraction, like early pixel art. The rich descriptions act as rooms or paths that the player uses to construct the world in their mind. I use this case study here to showcase the power of text and limited information, encouraging players to subconsciously generate the world for a deeply interactive and vivid experience. It should be mentioned that while the game is driven by a fantasy theme, the cave itself is based on Crowther's caving experiences and maps that he made within the Mammoth Cave located in Kentucky.

Veronica Graham's LODE





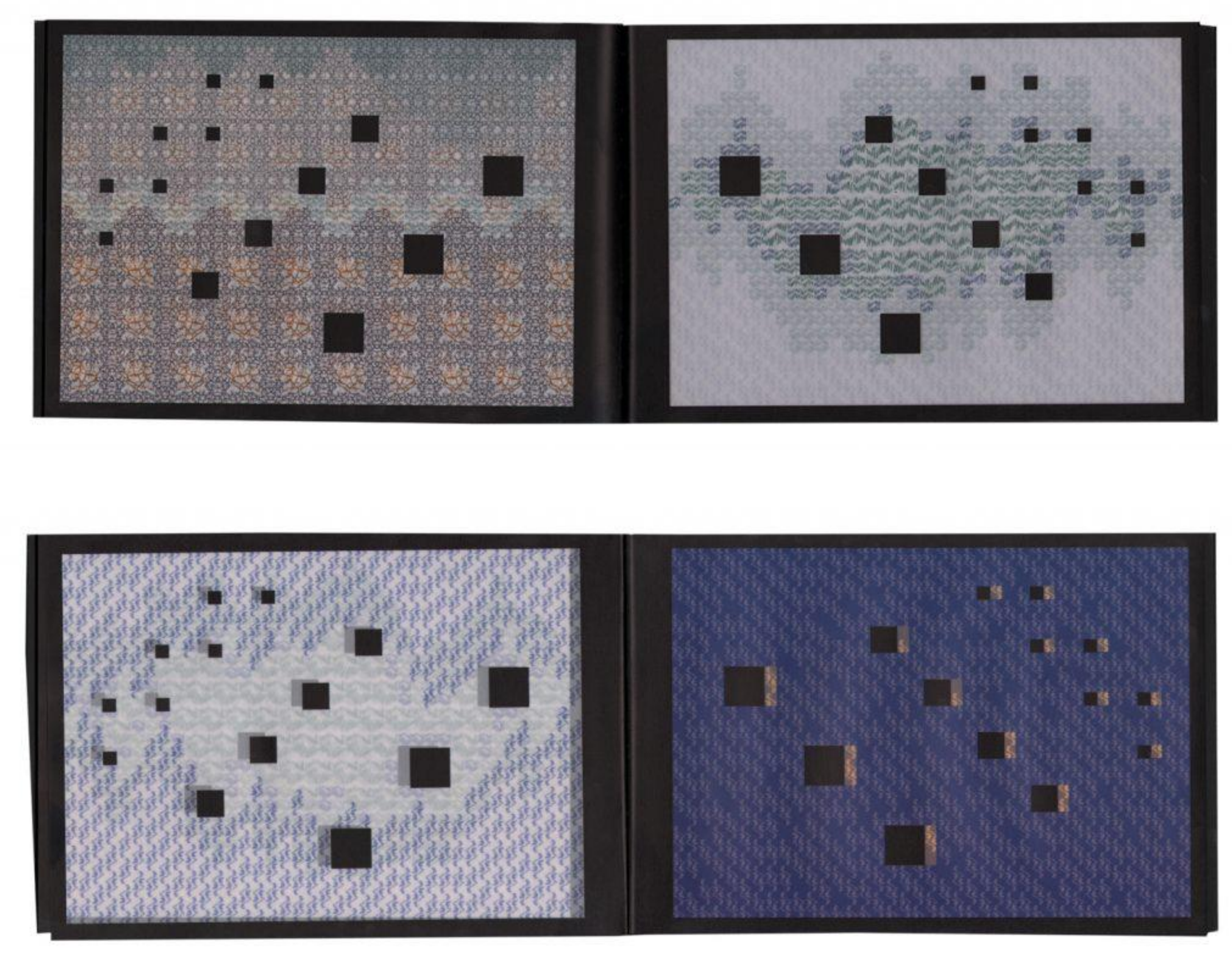


Figure 7 - https://vagraham.com/lode/

LODE by Veronica Graham was made in 2012. It is an artist book that tells the narrative of a landscape from a top-down perspective. Graham utilizes video game aesthetic rules in the form of tile and grid, common in retro games. Unlike video games, the book's pages are printed on vellum to remember the past, exist in the present, and peek into the future. Graham is challenging the idea of time, especially in relation to the environment. The environment is the main character here, going through tumultuous change: adapting to civilization, existing through disaster, recovering, and erased by what appears to be an ocean. Without words, the narrative of this character is easily understood and unwrapped by vellum and tile depictions.

I have placed it as a case study for its contemporary usage of grid and tile, a style that, by now, you may have noticed I am extremely fond of. Like Crowther's *Cave,* the tiled environment is abstract and leaves plenty of space for the player to imagine. This is an uncommon consideration in today's designed media. Abstraction in video games can become a well-organized negative space for player experience, especially for environments. The size of one tile could be a forest, a mine, a house, a village, or a meadow. It's up to the player to decide.

Graham's book is an excellent example of a transmedia project with how qualities of the digital can translate into a physical design artifact. This format opens questions for how this might be a game, or how some games might become books, which is an interesting design challenge.

Emissaries

Figure 8 - http://iancheng.com/emissaries

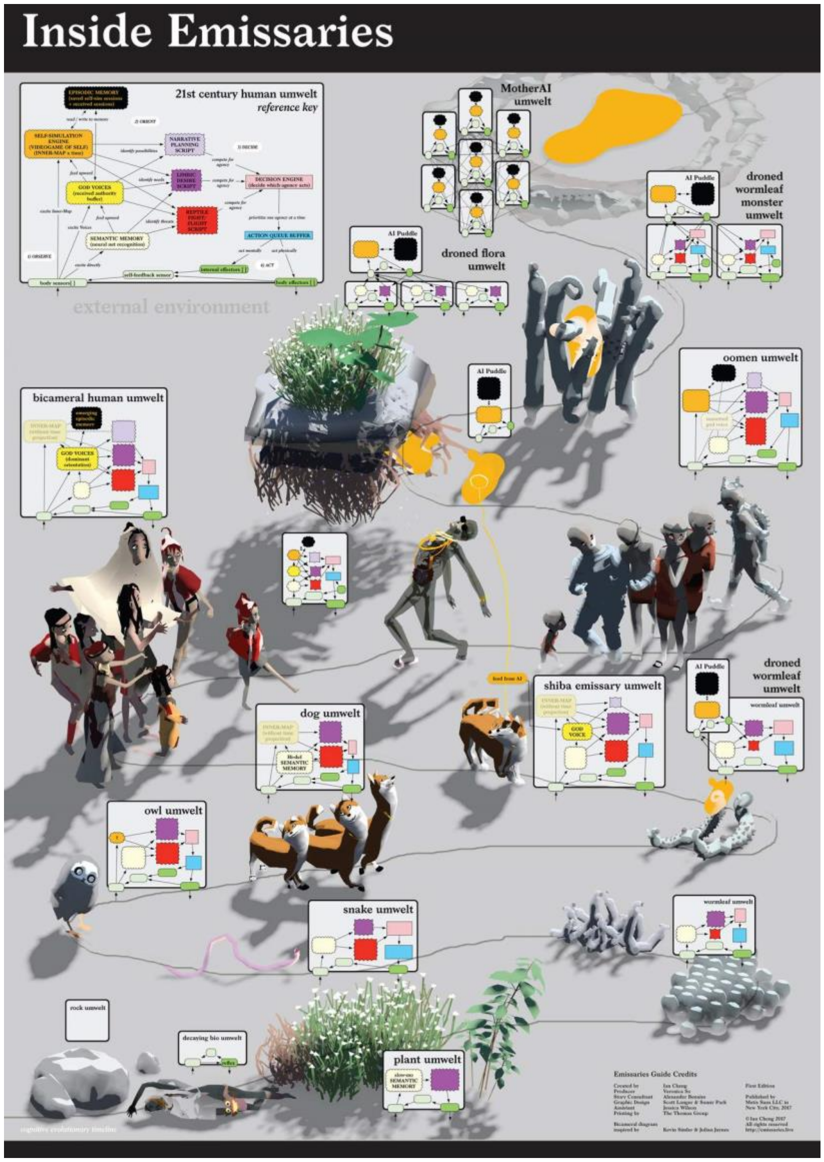


Figure 9 - http://iancheng.com/emissaries

Emissaries is a collection of three live simulation artworks that play themselves by the artist Ian Cheng, co-produced with his studio Metis Suns in 2015-2017. Cheng places a set of characters in an open-ended simulation, each evolving over time according to each character's systemic nature. These rules were developed via a narrative framework that Cheng worked on over time to create an intricate never-ending simulation, driven by the community's actions. There is no predetermined outcome, which permits the work to have variation, complexity and become a virtual ecosystem.

The simulations illustrate how modular elements when governed by simple rules can combine to mirror the visual aesthetic of an unpredictable natural environment. A real environment also can contain the quality of being grotesque, something that Cheng's simulations exemplify in what occasionally feels like glitches. These 'glitches' are designed for and challenge the viewers' digital and real environmental expectations.

This case study has encouraged me to reevaluate my role as designer and creator of systems which have the agency to change. Real environments are full of discovery and reinterpretation, something I hope to generate in my own games and simulation interactive media. This series of simulations continuously inspires me alongside the book paired with the series *Emissaries Guide to Worlding*.

Design Conjecture

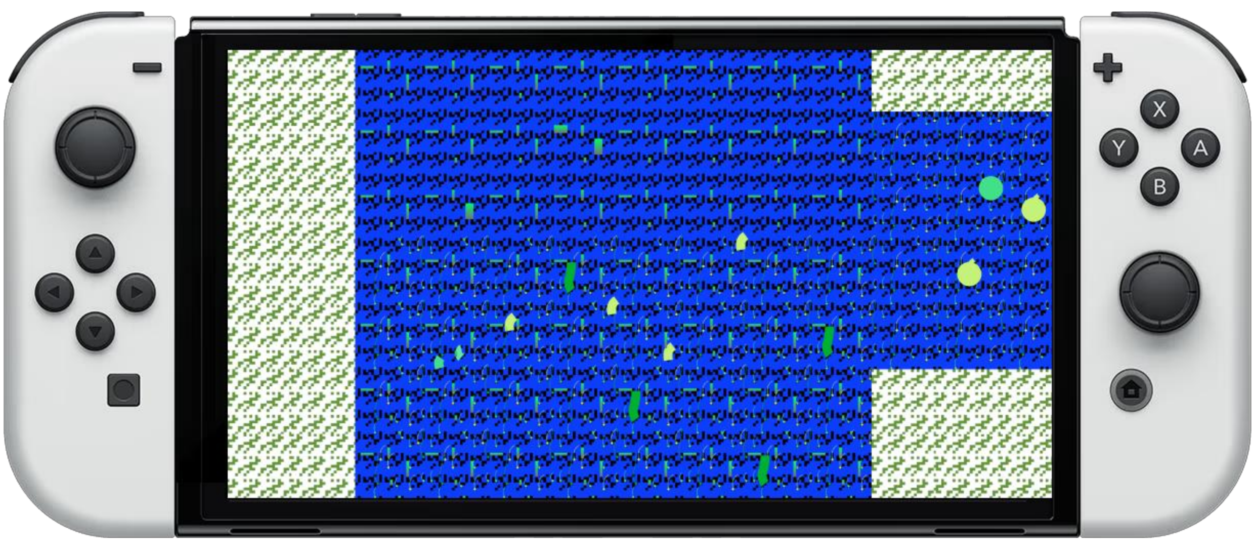


Figure 10

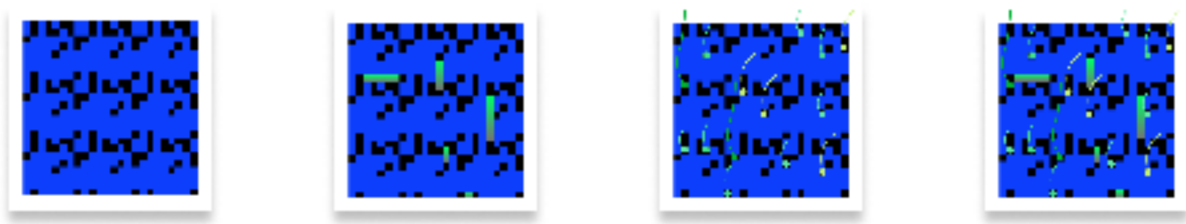


Figure 11

This is a study on taking the pixel graphic framework a few steps further. I have created a generator for making 8x8 pixel tiles that are copied and pasted to make up a 16x16 pixel tile. To add visual depth, I've used pixels as coordinates to spawn new elements. I mimic a shader to develop a gradient over the course of a few pixels and use vectors that appear as wavy lines. I am very excited about this sketch as it combines two visual typologies I've used before and look forward to seeing it animated. My belief is that this sketch and method embody the aesthetic quality of an ecosystem. I look forward to utilizing this visual framework further.

Further Readings

1. *2D Shader Development - 01 – Foundations* (Tufro, n.d.-a)
2. *2D Shader Development – 02 – Illumination and Shadows* (Tufro, n.d.-b)
3. *2D Shader Development - 03 - Procedural Texture Manipulation* (Tufro, n.d.-b)
4. *A Certain Level of Abstraction* (Juul, n.d.)
5. *A Framework for the Design and Evaluation of Architectural Tilesets* (Zhao et al., 2023)
6. *A Growing Disconnection From Nature Is Evident in Cultural Products* (Kesebir & Kesebir, 2017)
7. *A Simple Pipeline for Coherent Grid Maps* (Meulemans et al., 2021)
8. *Analyzing growing plants from 4D point cloud data* (Li et al., 2013)
9. *Animating Non-Human Characters Using Human Motion* (Kharitonova, n.d.)
10. *Codesign of graphics hardware accelerators* (Ewins et al., 1997)

11. *Construction of a Landscape Design and Greenery Maintenance Scheduling System Based on Multimodal Intelligent Computing and Deep Neural Networks* (Ji et al., 2022)
12. *Dancing With Systems* (*Dancing With Systems*, n.d.)
13. *Discovering Social and Aesthetic Categories of Avatars: A Bottom-Up Artificial Intelligence Approach Using Image Clustering* (Lim et al., n.d.)
14. *Forests in Digital Games - An Ecocritical Framework* (Thibault et al., 2022)
15. *Game graphics during the 8-bit computer era* (Collins, 1998)
16. *Geographical Aspects of Open-World Video Games* (Fraile-Jurado, 2023)
17. *GPU Shape Grammars* (Marvie et al., 2012)
18. *Green Computer and Video Games: An Introduction* (A. Chang & Parham, 2017)
19. *Harnessing generative grammars and genetic algorithms for immersive 2D maps* (De Oliveira Da Rocha Franco et al., 2023)
20. *Making Computer Graphics History Public: SIGGRAPH 2021 Retrospective Panel* (Gaboury et al., 2021)
21. *Narratives of environmental crisis in Chrono Cross: settler colonialism, inter-species conflicts, and environmental injustice* (Silva & Silva, 2023)
22. *Of Particle Systems and Picturesque Ontologies: Landscape, Nature, and Realism in Video Games* (Shinkle, 2020)
23. *Real Time Design and Animation of Fractal Plants and Trees* (Oppenheimer, 1986)
24. *Rendering Plant Leaves Faithfully* (Franzke & Deussen, n.d.)
25. *REPRODUCING YOSEMITE: OLMSTED, ENVIRONMENTALISM, AND THE NATURE OF AESTHETIC AGENCY* (Grusin, 1998)
26. *Retro arcade games as expressive and performative interfaces* (Nolan, 2021)
27. *Synthesizing Retro Game Screenshot Datasets for Sprite Detection* (Kim et al., n.d.)
28. *The Five-Dollar Model: Generating Game Maps and Sprites from Sentence Embeddings* (Merino et al., 2023)

29. *The Game of Video Game Objects: A Minimal Theory of when we see Pixels as Objects rather than Pictures* (Juul, 2021)
30. *Tile-based methods for interactive applications* (Lagae et al., 2008)
31. *TileCode: Creation of Video Games on Gaming Handhelds* (Ball et al., 2020)
32. *Video Game Romanticism: On Retro Gaming, Remakes, Reboots, Game Nostalgia, and Bad Games* (Bosman, 2023)
33. *Visual quality of the ground in 3D models: Using color-coded images to blend aerial photos with tiled detail- textures* (Roupé & Johansson, n.d.)
34. *Wang Tiles for Image and Texture Generation* (Cohen et al., n.d.)
35. *We are awash in digital light* (Turner, n.d.)
36. *Wet Ontologies, Fluid Spaces: Giving Depth to Volume through Oceanic Thinking* (Steinberg & Peters, 2015)
37. *Why Game Boy Color games looked like that* (*Why Game Boy Color Games Looked like That*, n.d.)

Topical Section 2: Interaction

Section Introduction

The nuanced interplay of virtual environments and user engagement is the theme of this topical section. Opening this section, you will find academic examinations of digital ecology encounters and how certain methods of interaction design may promote environmental education through play. A book review of *Playing Nature* confirms these thoughts as a growing phenomenon worth studying and developing. Alenda Chang puts together the methodological frameworks and creates what could be considered a playbook for game designers in considering designing for interaction in digital ecosystems.

My case studies of *Conway's Game of Life* and *Old School Runescape* are practical examples of environment centered play. The first acts as metaphor for life in emergent behavior visualized through tiles, whereas the other integrates environmental mechanics into the game to create interactive play which unknowingly to the player (myself) educates them to ecosystem dynamics. The third case study *Baba Is You* is a showcase of manipulating game rules via player to environment interactions. This last case study is closest to what I think of when I consider potential thesis projects. In moving rules around the screen, the player bends the simulation, just as a gardener would when moving plants around. My design conjecture is certainly influenced by *Baba Is You* and seeks to align interaction with simulation.

Altogether this section aims to provide a strong starting point for the study and design of environment centered interaction. These precedents are familiar to me through prior graduate research, as well as from many hours of playing the games myself. Since the sort of game mechanics discussed within this topical section are uncommon, a further study of their user engagement and appeal could be a next step in research.

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Digital ecologies: Materialities, encounters, governance

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Abstract

Digital technologies increasingly mediate relations between humans and nonhumans in a range of contexts including environmental governance, surveillance, and entertainment. Combining approaches from more-than-human and digital geographies, we proffer 'digital ecologies' as an analytical framework for examining digitally-mediated human–nonhuman entanglement. We identify entanglement as a compelling basis from which to articulate and critique digitally-mediated relations in diverse situated contexts. Three questions guide this approach: What digital technologies and infrastructures give rise to digital entanglement, and with what material consequences? What is at stake socially, politically, and economically when encounters with nonhumans are digitised? And how are digital technologies enrolled in programmes of environmental governance? We develop our digital ecologies framework across three core conceptual themes of wider interest to environmental geographers: (i) *materialities*, considering the infrastructures which enable digitally-mediated more-than-human connections and their socioenvironmental impacts; (ii) *encounters*, examining the political economic consequences and convivial potentials of digitising contact zones; (iii) *governance*, questioning how digital technologies produce novel forms of more-than-human governance. We affirm that digital mediations of more-than-human worlds can potentially cultivate environmentally progressive communities, convivial human–nonhuman encounters, and just forms of environmental governance, and as such note the urgency of these conversations.

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Keywords
digital ecologies, materiality, encounter, governance, digital geographies, more-than-human geographies, new media studies, digital entanglement

Introduction

Digital technologies increasingly mediate human–nonhuman relations in diverse settings including environmental governance, surveillance, and entertainment. Digitisation produces unique understandings of, and modes of access to, more-than-human worlds, and fundamentally reshapes conservation, environmentalism, and ecological politics (Jørgensen 2014). Early critics argued that these intensified human-technology relationships both produced and reflected public ecological *disengagement* (e.g., Balmford and Cowling 2006; Louv 2005; Kareiva 2008). Digitisation, they argued, was driving humanity's 'extinction of experience' (Pyle 1993) and fuelling 'nature deficit disorder' (Louv 2005). In response, 'reconnecting' with nature *beyond* the on-screen encounter emerged as "the mantra for addressing humanity's severance from the natural world" (Zylstra et al. 2014, 120). More recently, however, researchers and policymakers are increasingly embracing the optimistic idea that digital technologies can provide new forms of nature reconciliation. Such technofix solutionism is pervasive in discourses concerning all sorts of nature recovery programmes (see Fletcher 2017). In both of these ideological frames, the impacts of digitisation remain under-studied in conceptual and empirical terms (see Kuntsman and Rattle 2019).

In this paper, we present 'digital ecologies' as an analytical framework for researching digitised human-nonhuman relations which favours situated understandings of digitisation as a material, affective, and plural process. We feel this intervention is timely and of growing importance given the ubiquitous nature of digitisation in everyday life (Ash et al. 2018; Leszczynski 2020). We resist the false binary between connection/disconnection underpinning forms of eco-scepticism towards digital media (see Leszczynski 2015; McLean 2017; 2020) and the technofix prometheanism behind 'digital solutionism' (Kuntsman and Rattle 2019). Instead, following Taffel (2019), we employ the term *digital entanglement*. For Taffel (2019, 2), entanglement "refuses subject/object, nature/culture and representation/reality dualisms," whilst emphasising the inseparability of the material and experiential qualities of digital mediation. This position provides a useful basis from which to develop a holistic approach attentive to energy, matter, information, data, code, and attention (Taffel 2019). For us, entanglement highlights the potentials afforded by digital mediation and technologies, which do not *inherently* disengage nor reconnect humans to nature. Rather, they foster the potential for both, depending on socio-economic, ecological, cultural, historical, and geographical context (Altrudi 2021). They inaugurate new relationships that cannot be easily judged as harmful nor as a one-way ticket to a fantasised convivial techno-utopian future.

We begin by situating our interventions at the confluence of more-than-human and digital geographies, political ecology, and media studies in Section 2, developing a shared lexicon that seeks to bridge these subdisciplines. In doing so, we advance digital ecologies as an analytical framework and field of research covering the diverse range of approaches within this space (see Verma 2021).[1] Then, to help understand the nuances of digital entanglement, we develop our analytical framework across three key themes of long-standing interest to environmental geographers: materialities, encounters, and governance. This structure reflects key domains in which digitisation alters human–nonhuman relations, and offers a robust approach for examining the nature, ethics, and politics of digital entanglements: what they are, where they are, and why and to whom they matter.

Section 3—*materialities*—develops two arguments. First, digital mediation must be understood ontologically as a material process. This is crucial to conceptualising digital entanglement and attending to the political economies implicated in producing, enacting, and sustaining digital mediation. Second, we examine the environmental harms and socio-economic inequalities implicated in digitisation, which are often obscured by digital systems and ‘solutionism’, but illuminated through attention to digital materialities (e.g., Crawford and Joler 2018; Kuntsman and Rattle 2019). In section 4, we examine the affects, spatialities, and mediations associated with more-than-human digital *encounters*. Following McLean (2020), we conceptualise digital encounters as ‘more-than-real’ rather than impoverished approximations of the ‘real world’. Jettisoning ‘real’/’virtual’ distinctions, we focus on the specific spatialities in which digital encounters occur, examining the affects and affordances of technological interfaces, and the environmental subjectivities inaugurated both through and beyond ‘the screen’. Drawing from political ecology, we discuss how digital encounters are valued and commodified—producing ‘digital encounter value’ in settings including wildlife livestreaming and videogames—and point to the implications this has for contemporary forms of environmentalism. Remaining critical of commodified digital encounters, we note that digital encounters can, under certain circumstances, produce meaningful modes of care and concern outside capitalist relations, and encourage researchers to produce situated accounts of digital encounters across contexts. Finally, Section 5 brings the material and experiential aspects of digital entanglement together to examine novel forms of environmental *governance* inaugurated by the proliferating use of digital technologies. We explore how digital entanglement fosters uneven exercises of power, domination, and control, and ask how these technologies are themselves governed.

What material, social, and political economic relations are enabled, reinforced, or foreclosed through the digital mediation of more-than-human worlds? Our three thematic sections speak directly to this question, which helps to guide research into diverse instances of digital entanglement. *Materialities* places digitisation in an assemblage of material entities and relations, and foreground the socioecological injustices that underpin it. *Encounters* examines the experiential qualities and ways of being inaugurated by digital entanglement, and the political economies implicated in such encounters. *Governance* highlights how practices of digitising more-than-human worlds carries bio- and geo-political consequences. Thus, we propose digital ecologies as an analytical framework for elucidating instances of digital entanglement, foregrounding the interconnected potentials, politics, and responsibilities associated with the digitisation of more-than-human worlds.

A shared lexicon for digital ecologies

We begin by defining key terms—digital/digitisation and ecology—to establish a shared lexicon for digital ecologies, before intellectually situating our intervention in relation to a genealogy of related work. While work in more-than-human geography (Whatmore 2002; 2006) has explored the role of digital mediation in human-nonhuman relations (e.g., Blue 2016; Davies 2000; 2005; Nelson 2017; Ritts and Bakker 2021; Stinson 2017; Verma 2016; Verma et al. 2016; von Essen et al. 2021), there remains relatively sparse engagement between the disciplinary traditions of more-than-human and digital geographies (although see Dwyer 2021; McLean 2020; Nelson et al. 2022; Nost and Goldstein 2021; Prebble et al. 2021; Travis et al. 2023). As Leszczynski (2019, 21) notes, scant attention has been paid “to how nature as an assemblage of both human and non-human organic life intersects with or fits into what is often presented as a triad of technology-society-space relations." As such, digitisation is under-examined and under-theorised in more-than-human geography, while digital geographies could benefit from fuller conceptualisations of nonhuman agency and materiality as offered by more-than-human geographers. By conversing these geographical subdisciplines (alongside adjacent work in political ecology and media studies), this paper thus offers an analytical framework for future interdisciplinary research.

For Ash et al. (2018, 25), geography's 'digital turn' signals "a demonstrably marked turn to the digital as both object and subject of geographical inquiry," and the ways in which "the digital has pervasively inflected geographic thought, scholarship, and practice" (see also Ash et al. 2019). Despite this digital turn, the continued definitional ambiguity of 'the digital' is well documented (Berry 2014; Duggan 2017; Kitchin and Dodge 2011; Jeanneret 2000). Miller and Horst (2012, 3) define the digital as "all that which can be ultimately reduced to binary code, but which produces a further proliferation of particularity and difference." Digitisation converts the messy worlds of 'organic signals' into 'digits': the zeros and ones constituting binary code (Fish 2019; Lunenfeld 1999). As such, new media theorists suggest digitisation can be considered a contemporary form of inscribing, writing, and representing the world (Jeanneret 2000; 2013; 2019). This work attends to digital technologies as cultural 'objects' as well as analysing media content itself, exemplifying the heterogeneity of digitisation (Bolter and Grusin 1998; Jeanneret 2008; 2014 Jeanneret and Souchier 1999; 2005; Kittler 1986; Manovich 2001; Souchier 1996; Stiegler 1998). In this vein, Ash et al. (2019, 4) warn against singular 'monolithic' depictions of '*the* digital', instead invoking 'digital' in multiple ways to conceptualise the interconnected things produced through digital modes and mechanisms. In relation to the nonhuman world, these multiple processes of digitisation work, in turn, to produce a multiplicity of natures (Nelson et al. 2022). Digitisation thus shapes human–nature relations in multiple ways, enabling and foreclosing connections across more-than-human assemblages, events, and processes (Leszczynski 2015; Grusin 2015).

We turn next to the theoretical lens of ecology, which draws attention to how the process of digitisation is always underpinned by material relationships and infrastructures, despite these relations often being obscured. As such, ecology reminds us to examine "the materials that media are made of" (Cubitt 2016, 11). Ecology is conventionally understood as the biological study of interactions between living organisms and their environments. Promisingly, the term has also been adopted and reworked in the social sciences and humanities, notably by STS scholar and philosopher of science Isabelle Stengers (1997; 2005; 2010), precisely because of its focus on relations, assemblages, practices, and connections between more-than-human actants (Hörl and Burton 2017; Latour 2004; Latour et al. 2018; Tsing 2015). Inspired by Stengers, scholars have explored ecological frameworks for elucidating the relations between matter, bodies, and environments (Barad 2007; Bennett 2009; Braun and Whatmore 2010; Barua 2014; Lemke 2021)—key themes running throughout this paper. Digital geographers have likewise deployed an ecological lens to study the agencies of cybernetic matter such as algorithms, data, and malware (Amoore 2020; Dwyer 2019; 2021; Lupton 2016), and ecological metaphors are commonly deployed in organisational theory (Raptis et al. 2014), making ecologies a fruitful framing for interrogating the diversity of social and material relations that comprise digital entanglement.

While its use as a generic descriptor of systems has been common since the 1970s, 'ecology' also references the critical tradition of political ecology; a field of study examining how environmental conflicts and change are suffused with political, economic, and social power relations (Harvey 1996; Robbins 2020; Sultana 2020). More recently, scholars have begun to define 'digital political ecologies' (Tait and Nelson 2021), drawing on work in 'feminist digital geographies' (Elwood and Leszczynski 2018; Leszczynski 2018; Brooke 2021), 'feminist political ecology' (Harcourt and Nelson 2008; Sundberg 2017), and 'digital conservation' (Nelson 2017) to understand how political, economic, and social power dynamics play out and transform when environmental conflicts take place online or are digitally mediated (Tait and Nelson 2022; Nelson et al. 2022). Nelson and colleagues (2022, 4) call this body of work 'Feminist Digital Natures' and emphasise the importance of "power, embodiment, social difference, and emotions" in shaping how digital entanglement is differentially experienced, accessed, and governed. Their approach involves "understanding exactly who creates and uses digital technologies" and "how they are used or affectively engaged with" (Nelson et al. 2022, 4). Drawing inspiration from such work, digital ecologies research should not only offer critique of digital entanglement, but work towards just more-than-human worlds by seeking to create "possibilities of a liberatory digital politics for re-making our technologies and ourselves as digital subjects" (Elwood and Leszczynski 2018, 640).

Within geography and cognate disciplines, several terms have emerged to describe specific empirical or conceptual domains dealing with the digitisation of more-than-human worlds. Verma (2021) recently outlined some of the

Table 1. Selected research strands informing digital ecologies as an analytical framework, following the initial provocation of Verma (2021).

Term	Example	Empirical and theoretical focus
Digital conservation	Arts et al. 2015); Van der Wal and Arts (2015)	Critically inspects the technologically enabled knowledge practices and methods deployed in wildlife conservation
Anthrobscene	Parikka (2015a)	Attuned to the materiality of digital technologies, drawing attention to the uneven impacts of environmental degradation caused by the production of digital technologies
Media ecologies	Cubitt (2016); Fuller (2005)	Examines how mediation produces uneven political ecological relations and the linkages between digital media and environmental degradation
Nature 2.0	Büscher (2016)	A political ecological approach for examining how value is extracted from nonhumans online
Digital Anthropocene	McLean (2020)	Argues that both 'the digital' and 'the Anthropocene' are similarly "networked, material and abstracted spaces and concepts" (McLean 2020, 15) to examine the politics and affective experience of each in conjunction
Feminist digital natures	Tait and Nelson (2022); Nelson et al. (2022)	Examines the digital mediation of "socio-ecological relationships, particularly in the realms of conservation and environmental governance" with a particular focus on power, emotion, and embodiment (Nelson et al. 2022, 5)

most prominent terms in this growing lexicon, which inform the genealogy outlined in Table 1.

Encapsulating the bodies of work outlined above, 'digital ecologies' simultaneously invokes the (often harmful) *material* relations that underpin digitisation, the uneven geographies forged by digitised *encounters*, and the forms of environmental *governance* shaped by digitisation. Importantly, it is able to account for the multiplicity of digitisation as a process and the subsequent multiplicity of technology-society-environment relations constituting digital entanglement. It thus offers an apt analytical framework for interrogating emergent and interrelated digitised more-than-human worlds across geographical contexts.

Materialities of digitisation

Materiality is a foundational concern of more-than-human geography, highlighting the diversity of nonhuman actants implicated in the co-fabrication of social, political, and economic worlds (Whatmore 2006). This diversity is frequently obscured by the seemingly immaterial character of digitised worlds. Thus, within our digital ecologies analytical framework, we begin with materialities of digitisation to draw attention to the materials, devices, and infrastructures that are fundamental to the digitisation process. We turn first to the diversity of devices that digitise animals' lifeworlds.

Digitisation takes many forms and occurs via a plethora of devices across many geographical contexts. For instance, the use of digital monitoring technologies in ecological research has burgeoned since the mid-twentieth century, such that wildlife is now 'wired' (Benson 2010) with a continually advancing array of available loggers and sensors (Holton et al. 2021). Examples now include miniature tags for bees (Barlow et al. 2019), software that translates environmental data from a single tree into social media posts,[2] and radar sensors attached to albatrosses to police illegal fishing vessels (Weimerskirch et al. 2020). Certain devices generate ecological data on biotic and abiotic environments, from oceanic conditions to environmental radiation levels, facilitating the gathering of previously inaccessible data and the enrolment of nonhumans themselves as sensors and sentinels of environmental conditions (Gabrys 2018; Keck and Lakoff 2013). Digitised nonhumans, therefore, are now situated within wider digital milieus, presenting novel research opportunities for ecologists. For instance, in the Chornobyl Exclusion Zone in Ukraine, ecologists have used specially designed GPS-collars fitted with dosimeters to simultaneously understand the radiation exposure of wolves and their spatial range (Hinton et al., 2019).

Nevertheless, digital entanglement is always multiple, and partial: not everything can be neatly digitised, nor is digitisation a uniform process. Matter is inherently lost in the digitisation process, meaning digitised worlds are altered versions of the realities they portend to represent. In one sense, digitised worlds are *reduced* versions of the worlds they represent—usually, you cannot smell a digitised flower. But this argument is a red herring: rather than impoverished copies, digitisation produces difference and novel spatial constructions with their own sets of affects and affordances that cannot be equated with the 'real thing' (Kitchin and Dodge 2011; Kinsley 2014; Stinson 2017). Indeed, digitisation produces and shapes material worlds; it does not merely represent them. This is well exemplified by the case of 'smart forests', or other so-called 'smart' environments (see Moss et al. 2021). Once digitised by an array of technologies—including terraforming drones, sensors, AI, and robots (Gabrys 2020)—forests are remediated and circulated through devices which "co-constitute and mobilise forests as distributed sites that travel across platforms, data sets, observation technologies and participatory apps" (Gabrys 2021, 2). These processes allow different groups to then intervene in material forest processes in divergent ways, transforming forests and forest governance (Gabrys 2020; 2021; Gray 2020). Digitised worlds are thus: (a) mutable, translating between physical and cybernetic forms; (b) multimedial, materialising across a range of geographical and technological contexts; and (c) massive, existing in great number and frequency (see Rose 2016).

For Adams (2020, 18), digital devices give nonhumans "a second life lived through the continuous unspooling of location data" moving "in server farms and temporary storage in its transmission from animal to satellite and down again." In an era of extinction, some digital animals may outlast their corporeal counterparts. Nevertheless, the infrastructures underpinning digital mediation are themselves subject to the process of decay and require ongoing replacement (Taffel, 2022). Given this, it is concerning that institutional environmental regulations continue to overlook the impacts of these energy-intensive, maintenance-requiring digital infrastructures (McLean et al. 2022). As Kuntsman and Rattle (2019) note, 'digital solutionism' continues apace with little concern for digitisation's deleterious impacts. Without systematically accounting for the materialities of digital devices, the promise of digital technologies for environmentally-positive futures is debatable (Kuntsman and Rattle 2019). Thus, we turn next to the material ecologies of media themselves—both active and obsolete—littered around the world (Gabrys, 2011).

In contrast to common imaginaries of digital worlds as immaterial 'clouds' (see Monserrate 2022), media ecology theorists stress that environments do not simply surround media but run through and enable them (Kember and Zylinska 2012; Parikka 2015a; 2015b; Pickren; 2014; 2016).[3] Indeed, a long tradition in media theory—which culminated in the 'infrastructural turn' around the turn of the millennium (Bowker and Star 2000; Edwards et al. 2009; Star 1999; Star and Ruhleder 1996)—examines the infrastructures underpinning digital mediation. This research foregrounds the materiality of data centres (Bratton 2016; Hogan 2018; Holt and Vonderau 2015; Parks and Starosielski 2015), undersea cables (Starosielski, 2015), and cloud infrastructures (Peters 2015; Amoore 2020) amongst other things, and their role in geopolitical and environmental inequalities (Franklin 2021). It is not only digital hardware that causes socioenvironmental damage, though; software, too, can be more or less energy efficient (Taffel 2019). For instance, each Google search emits 0.2 g of CO_2 (Cubitt 2016).

Like with other commodities, the production of digital technologies deepens the socioeconomic inequalities associated with resource extraction, commodification, and waste disposal (Taffel 2012; 2019; 2022). For example, in the Katanga Copperbelt, Democratic Republic of Congo, where more than half of the world's cobalt is mined, workers are exposed to poor working conditions, unjust wages, and environmental toxins through mining a mineral essential to lithium-ion batteries now found in mobile phones and other digital devices worldwide (Tsurukawa et al. 2011; Nkulu et al. 2018). Cubitt (2016) outlines how 70% of all mined uranium—often used to generate the electricity which powers digital devices—comes from Indigenous territories and is often acquired through exploitative neo-colonial practices. For example, the Australian government breached international human rights laws while extracting uranium from Indigenous lands. Examples such as this abound, and the relationship between digital media and capital is at the root of this exploitation (Cubitt 2016). Digital materialities extend beyond metals and minerals, too, contributing to the production of plastic, radioactive waste, and other forms of pollution (Taffel 2016; 2021).

The technoscientific ability to understand earth systems is dependent upon the extraction of the very same earthly materials under examination. The observed materials are themselves integral to the building of digital sensing devices. Parikka's (2012) neologism 'medianatures' captures this ironic interdependence. Elsewhere, Parikka (2015a) highlights the long-lasting material remnants of digital devices, raising awareness of the extractive processes implicated in their production and their toxic lives and afterlives (see Palmer 2021), which form technological debris scattered globally. What ends up as a toxic contaminant in one place begins as a rare earth mineral elsewhere, briefly animating a technological device in the interim. Gabrys (2011) similarly highlights the ubiquitous and long-lasting toxic rubbish by-produced through digitisation. Understanding digital technologies through this material lens thus involves widening the ontology of 'digital technologies' to include vast material infrastructures produced through exploitative extractive economies. Akin to follow-the-thing methodologies (Cook et al. 2004), tracing the lives of digital devices from production to disposal reveals the inherent materiality of digitisation (see Palmer 2021).

In addition to labour exploitation in the extractive industries underpinning digital technologies, labour is also exploited *through* digital platforms (Terranova 2000; Marres 2017). This is prominent in the context of crowdsourcing for environmental projects (Woodcock et al. 2017) where volunteers' time, skill, knowledge, and energy become digitally obfuscated (Dagiral and Peerbave 2012; Scholz 2015). This becomes particularly problematic when enterprises are heralded as democratising science, but in reality, engage volunteers as 'cogs in a machine' to execute pre-set tasks under disciplined supervision (Benson 2017; Woodcock et al. 2017). Increasing smartphone use and internet accessibility blurs distinctions between producers and consumers of nature content online. But while Büscher (2016) laments the rise of so-called 'prosumers' under platform capitalism, others note the 'democratising' impact digital technologies can have (Silk et al. 2021). We return to this in more depth in the next section.

Foregrounding the materials and infrastructures underpinning digital entanglement shows how digital media themselves fundamentally affect the environments, interactions, and bodies of the nonhumans they were invented to observe. Epistemic practices involving digital technologies are thus tightly entangled with their subjects of study. A focus on materiality connects sparse spatiotemporalities to illuminate the mineral lives of digital media before their use, the extractive labour politics that bring them into being, and their environmentally deleterious afterlives perpetuated when rendered obsolete by capitalist economies (Gabrys 2011; Taffel 2022). Bringing attention to digitisation as a material process also draws together disparate material relations often obscured by popular notions of 'the cloud' that are culturally tacked onto digitality. Materiality thus offers digital ecologies a lens to consider new digital spatialities, subjects, beings, relations, and politics. In addition, it gestures to how digital media are rooted in relations of extractive and colonial capitalism and, in doing so, points to possibilities for conceiving of alternative digital subjectivities and politics (see Elwood and Leszczynski 2018). Having examined the material basis of digital entanglement, we turn our attention in the next section to its experiential aspects and the political economies invoked via more-than-human digital encounters.

Digital encounters

An encounter takes place when two or more different entities come into contact, thus reconfiguring identities, space, and political economies (Barua 2015; Wilson 2017). More-than-human encounters occur within 'contact zones' which unsettle borders between humans and nonhumans (Haraway 2008). In this context, digital entanglement involves mediated encounters in which ecologies are experienced and made sense of. So, what happens when contact zones are digitally mediated? How does digitisation transform encounters with the nonhuman world? And what is at stake politically and ethically when species (sort of) meet digitally?

Digitisation allows humans to amplify and alter "possibilities of perceiving, feeling, knowing and acting" (Carbone 2019, 97-98). Furthermore, it 'reorients' senses and bodies to different environments, opening up new spaces of political opportunity (Nelson et al. 2022). We identify two ontological shifts inaugurated by digital encounters. First, digitisation enables new ways of encountering nonhumans that were (and are) encountered without digital mediation. These are encounters that took place before digitisation but which are now mediated by it. Second, entirely novel encounters are facilitated by digitisation, involving aspects of nature inaccessible to encounter without the use of digital technologies. This section explores how digitisation transforms encounters and mobilises them to generate value, foster conviviality, and facilitate novel insights into the nonhuman world. We begin by interrogating *where* digital encounters take place.

Digital encounters—from entertainment to scientific research—most often take place via screens, where digitised nonhumans are commonly encountered as audio-visual renderings. This involves both high-definition imagery and sound, or rudimentary abstractions like GIS dots-on-the-map. Given visual bias, screens have become the most dominant technology for mediating ecologies and are "a central component of an increasingly digital world" (Silk et al. 2021, 1130). They tend to produce encounters imbued with a fundamental 'flatness' (Yang 2021) and 'partiality' (Haraway 1988). For this reason, screen-based encounters are often considered disembodied versions of corporeal encounters. But while digital encounters *may* involve fewer sensual elements of the nonhuman world, they are not disembodied: screens produce "a world for the viewer," generating "affects [which] resonate to form a territory for the body" (Ash 2009, 2116). Screens thus create novel socialities and spatialities (Boellstorff 2020). For Ash (2009), their ability to forge connections between bodies and environments even renders screens 'ecological'.

Digital encounters are intensely affective. As a result, they are often put to work for political, social, and economic ends, both conservative and progressive; coercive and empowering (Chasseray-Peraldi 2020; Dyer-Witheford and de Peuter 2009). For example, Berland (2019) directly links colonial menageries and digitised animals, noting that both were/are enrolled to facilitate the commodification of nature in exploitative ways. Here, digitised animals are used as charismatic entertainers to generate profit for corporations, resembling the objectification of animals in colonial menageries to symbolise status, wealth, and power. Contrastingly, Hawkins and Silver (2017) examine how Inuit activists have used digital media and social media platforms to challenge colonial views of their hunting practices as cruel, a sentiment perpetuated by uninvolved celebrities and animal rights organisations online. Digital technologies, including hegemonic tools like those used for surveillance, can thus be (and often are) subverted towards progressive ends (e.g., Engelmann et al. 2022). This exemplifies how "digital technologies can open up new possibilities of multi-species relating through embodied, affective, emotional interactions, and reciprocity" (Nelson et al. 2022, 5). As these examples show, the political potential of digital encounters is highly contingent, making it imperative to examine the specific uses of digital technologies in situated practices to understand the pros and cons they engender, and for whom.

Despite the potential for digital encounters to be either progressive or conservative, much scholarship regarding digital human-nature encounters remains rooted in critical discourses concerning commodification and surveillance. This literature holds that digital encounters "stimulate and complicate the commodification of biodiversity," allowing new forms of nature commodification to take place (Büscher 2016, 726). Büscher (2016, 726) suggests these spectacular forms of commodification produce 'Nature 2.0'; a reimagining of "ideas, ideals and experiences of ('pristine') nature" (see also Mitman 1999). Digital encounters with Nature 2.0 involve the production of digital encounter value (see Turnbull et al. 2020). 'Encounter value' is produced when species meet. It is considered the third form of capitalist value alongside 'use value' and 'exchange value' as theorised by Marx (Haraway 2008; Barua 2016). *Digital* encounter value is thus generated through digitally mediated encounters when human and nonhuman bodies are not necessarily proximate in time and space, fundamentally altering the nature of how value is produced by involving a range of distributed human, nonhuman, and technological agencies (see Oliver 2021). This value production "often occurs through spectacle, celebrity, and popular media-based content encouraged in many digital spaces" (Nelson et al. 2022, 5). 'Lively capital' (Barua 2016) is thus produced at and circulates between, a wider range of sites in the age of digital entanglement, the nuances of which should be explored in future research.

On social media, digital encounters most commonly occur with familiar species, involving spectacular, stereotypical, and repetitive representations (Igoe 2010; Somerville et al. 2021). The 'Instagrammable outdoors' reoccurs as users adhere to pre-set cultural scripts in the pursuit of likes and shares (Arts et al. 2021). Charismatic animals can even attain celebrity status in digital form (Barua 2020; Dale Joshua et al. 2016; Despret 2016), while smaller-bodied taxa, are often excluded from online digital encounters (Silk et al. 2021), creating skewed understandings of 'pristine' nature among broad publics (Büscher 2016). Digital encounter value is thus associated with 'spectacular accumulation' (Barua 2017; see also Goodman et al. 2016), which generates profit by stripping individual nonhumans from their ecologies to render them marketable.

However, not all digital encounters render nonhumans spectacular through ecological and historical decontextualisation. Digital technologies offer real-time, widespread access to the daily lives of nonhumans globally (Kamphof 2011; 2013; Loomis et al. 2018), where we see promise for convivial practice. Turnbull et al. (2020) examine popular livestreamed animal encounters during COVID-19 lockdowns, where organisations actively situated nonhumans in ecological contexts to produce digital encounter value. One example involved 'virtually petting' free-roaming dogs in the Chornobyl Exclusion Zone, where online tourists learnt of the dogs' life histories. In 2021, Cambridge University Botanic Garden livestreamed the rare blooming of the moonflower (*Selenicereus wittii*)—accompanied by public dialogues regarding the species' natural history. Encounters livestreamed 24-hours-a-day, like peregrine falcon 'nestcams' (Searle et al. 2022), allow for recurring encounters (Kamphof 2011), where affective bonds between human viewers and individual animals can be forged. Livestreamed encounters often cut against spectacular accumulation, broadcasting a range of species doing 'boring' everyday things, which appeal to those in search of calming slowness (see Peplin 2016). Digitisation thus fosters the potential for less-exploitative, consciously situated, and more convivial human-nonhuman relations.

The real-time insights gleaned by livestreaming technologies also allow for significant scientific insights to be made into a range of species' biologies and ecologies globally. Emerging digital technologies have the capacity to produce on-screen encounters with otherwise un-encounterable aspects of nonhuman life. Through a case study of peregrine falcon 'nest-cams', Searle et al. (2022) detail how digital encounters allowed for previously unachievable observations that generated insights fundamentally reshaping understandings of peregrine ethology (see also Kettel et al. 2016). Similarly, Crickette Sanz and colleagues have used digital camera traps to observe wild chimpanzees without relying on human habituation to study their behaviour 'in the wild' (Musgrave et al. 2016). Novel ecological insights can thus be facilitated with little intervention into the lives of at-risk species through digital encounters.

But while digital encounters bring distant wildlife into homes and laboratories around the world, this can have negative consequences, especially in conservation contexts where 'less interventionist' technologies like camera traps and drones are used (Rovero and Zimmerman 2016; Sandbrook et al. 2018; Wich and Koh 2018). As Kiggell (2021) notes, the increased use of digital remote sensing technologies among ecologists means that less time is spent in the field interacting with implicated communities, which generates impoverished understandings of complex nonhuman lives, including the ways in which they relate to humans (Collard 2018; Parks 2019). Digital encounters can displace decision-making away from local communities and their situated knowledges, which in turn reinforces colonial knowledge production practices that plague the history of global conservation (Adams 2019; Kiggel 2021). The very notions of 'the field', fieldwork, and field encounters are thus reconstituted via digital technologies (Benson 2016), and new questions are raised concerning the ethics of access to traditional 'fieldwork' and the forms of enquiry necessary for producing knowledge about the world (Guasco 2022). Nevertheless, digital encounters—like all encounters—always offer partial perspectives. When inaugurated for resarch purposees, digital encounters must thus be situated in broader socioecological contexts, and often supplemented with other forms of enquiry.

While the spatiotemporal displacements caused by digitisation can imply immateriality, digital encounters always remain rooted in physical encounters and material relations (see Chasseray-Peraldi 2020; 2022; Fish 2020; Hoelzl and Marie 2022; Pink 2011). The very presence of digital devices and infrastructures in certain places can thus have detrimental effects on local communities, some of whom oppose and resist their deployment. We return to the implications of this for environmental governance in the next section.

Digital encounters, moreover, are commonly non-reciprocal and the intimacies they inaugurate can be problematic (Marres 2017; see also Koch and Miles 2021). Concerns are raised that one-sided encounters breach the privacy of nonhuman animals (Collard 2016; Mills 2010), as well as people (Sandbrook et al. 2018). The infringement of nonhuman privacy is only beginning to be problematised (Paci et al. 2022). Digital technologies now capture animals in their most vulnerable states—such as nesting, giving birth, mating—which they go to great lengths to conceal in the wild. An additional issue with this involves putting endangered animals at increased risk of undesirable in-person encounters, or even poaching, by people who determine their whereabouts online (Silk et al. 2021). This unidirectional relation, though, is not always the case. Joanne Tate (2021), for instance, notes how, during COVID-19 lockdowns, an aquarium in Tokyo encouraged the public to video call its resident garden eels as a means of engaging, helping, and caring for them. The zoo believed the eels' health and sociability would be improved through these digital encounters. Contrary to the risks of poaching just identified, civilians have also become watchdogs of the security and well-being of wild animals on livestreams, alerting authorities to risks of poaching or urging intervention in the case of harm (Pschera 2016; Searle et al. 2022). Digital encounters thus take a range of both care-full and harmful forms.

Beyond digital encounters with actual wildlife, encounters with entirely novel natures are facilitated by digital technologies. Such encounters often take place in videogames, virtual or augmented realities (Nelson et al. 2022; Tyler 2022; Wallin 2022), and imagined or designed worlds. While at first glance this may seem ecologically irrelevant, there are now approximately 2.7 billion gamers worldwide, and a variety of videogames engage themes relating to ecology, making them important contact zones between humans and avatars of the nonhuman world (Chang 2019; Dorward et al. 2017; Fisher et al. 2021). For many, such encounters are a primary site where nature is made sense of. Certain videogames are explicitly concerned with conservation issues (Sandbrook et al. 2015), species loss and extinction (Büscher 2016), and animal management (Burroughs 2014). Some, like *WilderQuest*, even have the explicit remit of combating ‘nature deficit disorder’ in children (Louv 2005; Fletcher 2017). Crowley et al. (2021) suggest certain action-adventure games should be taken seriously as conservation education tools by highlighting the ability to play as ‘naturalists’ completing storylines in ‘eco-friendly’ ways.

But ‘eco-friendly’ videogames often sidestep issues relating to power over natural resources which are, in fact, drivers of the biodiversity crisis (Fletcher 2017). Indeed, commercial videogames continue to exhibit forms of ‘Casual Empire’ by depoliticising and reframing colonial encounters as ‘adventure’ (Harrer 2018). Scepticism towards these games is compounded by the fact that digital encounters can be manipulated, misleading viewers with fabricated versions of nature (Louson 2021; Silk et al. 2021). Furthermore, apps geared towards nature engagement often demonstrate a preoccupation with self-monitoring and competition—i.e., gamification (Arts et al. 2021). Even accredited scientific initiatives which log species data, like ‘Artdatabanken’ in Sweden, are now pressured to satisfy citizen scientists’ competitive urges (Peterson et al. 2021). Indeed, developers often operate with the primary purpose of enhancing user-experience rather than facilitating convivial more-than-human relations. However, emerging research in digital ecologies is beginning to show that focusing solely on in-game, in-app, or on-screen encounters is an ineffective approach. Indeed, digital encounters—gaming or otherwise—regularly incite action beyond the screen, such as seeking out a physical encounter with a bird from user coordinates logged in a database (see Turnbull et al. 2022; Von Essen et al. 2021).

Technological improvements in miniaturisation also allow unfamiliar aspects of nature to be depicted (Verma et al. 2016; Silk et al. 2021). At the genomic scale, for instance, emerging digital technologies are allowing scientists to encounter what was previously speculated to be ‘biological dark matter’ (Marcy et al. 2007). For instance, *Meta AI* (previously Facebook) recently predicted the existence of 600 million microbial protein structures through machine learning (Callaway 2022). Microbial ecologies are thus made knowable and visible through screen-based encounters and digital mediation and speculation (Almeida et al. 2021; Lapidus and Korobeynikov 2021). Such interventions involve the production of novel digital realities in which nonhuman life can be governed at the molecular scale. These instances reflect a broader display of biopower in which nonhuman life is quantified, valued, and commodified through the digitisation of genomic information (Lonkila and Kaljonen 2018). Digital technologies not only engender novel governance techniques but render new aspects of the nonhuman worlds governable, which we turn our attention to in the next section.

Digital environmental governance

Digitisation generates opportunities for understanding pasts, governing presents, and forecasting futures (Kitchin 2015; Amoore 2020), and participates in a culture of control and prediction. Digitisation also reshapes the governance of technologies themselves. Mark Bevir's (2013, 1) definition of governance—"all processes of governing" regardless of by whom and for which purpose—reflects the conceptual plasticity of governance, providing suitably broad scope for this paper. In this section, we outline the role of digital technologies in the uneven exercise of power, considering how technologies transform environmental governance. This has diverse implications for both nonhumans and humans, stemming from the ways digital technologies and the data they produce can redistribute expertise and authority to novel actors (Mattern 2017).

Environmental governance and conservation policies increasingly rely on data from monitoring devices such as biologgers and camera traps, and the models used to analyse, visualise, and conduct predictions based on this data (Benson 2010; Collard 2018; Hussey et al. 2015; Kays et al. 2015). As Grusin (2015, 147) suggests, "data are now gathered on almost everything humans and nonhumans do," with proponents of data-driven governance seeking "a world in which all humans and nonhumans are networked and mediated." Governance thus relies on the proliferation of digital technologies to satiate its appetite for evermore data to facilitate 'smart' or 'precise' governance interventions. Such interventions are often championed for their capacity to operate in real-time (Bakker and Ritts 2018; Bakker 2022), such that governance can function in response to the world rather than pre-empting it (Chandler 2018). Real-time governance is generally supported by scientists, publics, and an expanding analytics industry championing rapid registration of and response to worldly processes (Beer 2017).

Digital technologies thus facilitate a plethora of instantaneous interventions into diverse ecologies. For instance, they are implicated in 'precision farming', which entails unprecedented surveillance of—and intervention into—biological processes via automated monitoring and response (Pylianidis et al. 2021). Devices like mooON —a 'fitbit for cows' (Sharma 2019)—are used to monitor bovine physiology, optimising practices such as artificial insemination and preventative healthcare (Stellapps 2021). Moreover, entire agricultural systems are now represented as 'digital twins'—simulated models that reflect real-time changes in the system. The company 'Growing Underground', for instance, has developed a digital twin of its vertical farming operation designed to "monitor, learn, feedback and forecast information that will make the real-life twin work better" (Walsh 2021, np; see also Jans-Singh et al. 2020). Through these systems, environmental variables can be sensed and modified, and efficiency and productivity maximised (Gabrys 2014; Green and Chandler 2014; Rose and Chilvers 2018; Wolfert et al. 2017).

Digitally-enabled surveillance now applies to wildlife, agricultural, and laboratory animals, as well as entities like rivers (Duncan and Levidis 2020), oceans (Braverman and Johnson 2020; Drakopoulos et al. 2022), and atmospheres (Gabrys 2016). Such surveillance often entails the enrolment of digital technologies into coercive forms of biopolitics. Yet, just as digital encounters are not necessarily spectacular, digital technologies are not always involved in hegemonic biopolitical governance. A phenomenon akin to 'the Foucault effect' (Nustad and Swanson 2021) prevails in critical scholarship, denoting a tendency to label *all* uses of digital technologies to govern as oppressive biopolitical techniques. While digital technologies *are* often used in surveillance contexts, they can also generate other, potentially positive, possibilities. Whitney (2014), for instance, regards the bird's-eye view offered by geolocating tags not as a manifestation of the 'god trick' (Haraway 1988), but as a form of situated knowledge allowing access to an animal's environment. Real-time monitoring, in particular, has consequences beyond hegemonic governance and can enable more convivial more-than-human relations to emerge (von Essen et al. 2021). 'Nestcams', for instance, allow publics to report wildlife crime and accidents, like when fledglings fall from nests (see Chambers 2007; Searle et al. 2022), whilst the Deepwater Horizon 'spillcam', arranged by popular public demand, acted as a livestreaming witness to environmental catastrophe and allowed scientists to contest BP's impact estimates (Jue 2020).

Digital technologies, moreover, often enrol nonhumans as actors or labourers in the governance process. The potential for ecologies themselves to guide governance via networks of sensors is expressed by Lenton and Latour's (2018) conceptualisation of 'Gaia 2.0': a self-regulating and self-aware Earth system. In Gaia 2.0, organism-sensor assemblages connected to the 'Internet of Animals' (Curry 2018; Max-Planck-Gesellschaft 2021) conduct ecological monitoring and shape governance. This includes far-ranging examples such as 'albatross cops' (Stokstad 2021), 'elephant seal oceanographers' (Forssman 2017), and 'poacher-detecting herbivores' (de Knegt et al. 2021). These nonhumans are rendered infrastructural and contribute actively to desired systemic properties such as biodiversity and flood resilience (Barua 2021; Braun 2014; Manaugh 2015; Wakefield and Braun 2019). Dynamic ocean management systems which monitor ecological conditions and the movement of protected species to inform marine management decisions in real-time offer one example of this already in operation (Bakker 2022; Maxwell et al. 2015; Ritts 2017; Ritts and Simpson 2022).

Whilst we see potential in digital technologies for enhancing environmental governance in progressive ways, a suite of unresolved issues remain. First, monitoring technologies can negatively affect the animals being monitored, either via the research process itself (e.g., the effects of tagging an animal) or by creating new avenues for policing, exclusion, and exploitation (Phillips et al. 2003; Sandbrook et al. 2018; Wilson et al. 2019). This applies to the humans caught in an animal's orbit, too, where breaches in privacy are enabled when technologies collect private data or imagery without consent, like camera trap imagery (Sandbrook et al. 2018). As digital methods proliferate, de-contextualisation becomes more of an acute issue. This is most evident in conservation planning's reliance on digitally-simulated animal movement. The 'minimal animal' (Benson 2016) in these simulations is divorced from observations of actual living animals (Bergman 2005). As Kumar et al. (2021) note, models for predicting wildlife movement produce 'minimal ecologies' in which broader ecological relations are obscured (see also Kumar et al. 2022). These practices have been critiqued for deepening conservation's biopolitical tendencies towards forms of population management neglectful of individual animals' experiences (see Srinivasan 2014; Braverman 2015; Kumar et al. 2022), and digital technologies still require 'ground-truthing' to ensure equitable and responsible conservation outcomes.

Second, digital technologies may even be *designed* to kill, as with autonomous vehicles that automatically detect and kill starfish which damage the Great Barrier Reef (Dayoub et al. 2015; Dauvergne 2020). These activities are often performed by wildlife managers—as with the culling of tracked wolves who regularly predate cattle (Marris 2017), and the elimination of potential predators of endangered species (see Reinert 2013). Whilst "killing for conservation"

(Duffy 2000) and the "entanglement of harm and care" in conservation practice (Srinivasan 2014, 501) have long been prominent features of the field, the efficiency and non-reflexivity with which this can be achieved using digital technologies, and the lack of common governing principles, requires critical scrutiny in future research.

Third, in relation to the above examples concerning sentinel animals, there remains a risk that wildlife is valued solely in terms of its "sensory-driven utility" (Barua, 2021, 69); that is, objectified as data producers. This is likely in a context where data is highly valued and can thus be sold to private companies, insurance agencies, and more. Such animals are not only enrolled as environmental sensors, but also into processes of capital accumulation. Such concerns extend to contexts where nonhumans are put to work under the framework of 'ecosystem services' and 'natural capital' (Helm 2016). Varied digital technologies—from drones measuring organic carbon (Stanley 2022) to blockchain technologies used to trade environmental goods as exchangeable tokens (Stuit et al. 2022)—further translate organic processes into value-able, marketable entities. Digital technologies, in this way, help to "make nature exponentially more available to the uses of capital and empire" (Lehman 2020, 165), enabling processes of valuation that political ecologists have critiqued for objectifying, commodifying, and de-contextualising nature, while failing to deliver equitable outcomes (Apostolopoulou and Adams 2017; Büscher and Fletcher 2015; Smith 2007).

Fourth, as noted by Bakker and Ritts (2018), real-time environmental governance does not necessarily guarantee ecological wellbeing and may favour certain actors over others. The risk is that governing could be reduced to the real-time regulation of the neoliberal status quo, leaving major (infra)structural issues unaddressed (Chandler and Pugh 2021). Indeed, whilst digital governance tools are often celebrated for addressing issues spanning poverty, food security, and biodiversity loss, they also raise important concerns around data sovereignty, digital divisions and dispossessions, and the actors involved in decision-making (Adams 2019; Bakker and Ritts 2018). Equally, critical scrutiny of the shifting sites and forms of expertise and decision-making—particularly towards those who design technologies and analyse and communicate data—is necessary (Nost and Goldstein 2021; Goldstein and Nost 2022; Nadim 2021; Turnhout et al. 2014). As knowledge production and the operation of power increasingly occur algorithmically, governance can itself be conceived of as a fundamentally more-than-human achievement—distributed across human actors, sensors, data infrastructures, and algorithms (Machen and Nost 2021; Amoore 2020). Digital technologies might even entail notable reductions of human agency in environmental governance through reliance on artificial intelligence (Fish 2020; see also Drakopulos et al. 2022). And yet, digital technologies are often embedded with (and perpetuate) the biases and exclusionary practices of the human groups from which they emerge (Graham and Dittus 2022; Silk et al. 2021), raising pressing questions regarding who gains and who loses amidst digital entanglement.

In response to the aforementioned issues, digital technologies themselves require robust governance frameworks to ensure their more equitable use. However, efforts to responsibly govern the use of new technologies are often outpaced by their deployment and development (di Minin et al. 2021; Sandbrook et al. 2021). For example, intentional or accidental collection of data on people via conservation monitoring technologies has generated growing concern (Sandbrook et al. 2021). Camera traps, for example, generate 'human bycatch' (unintentional images of humans), with no common framework for the handling of these data (Sandbrook et al. 2018). Similar issues have been identified for drones (Sandbrook 2015) and for the use of social media data in ecological research to inform decision-making (di Minin et al. 2021). Data collected for biosecurity monitoring has also been exploited for financial gain when sold to third parties (Corcoran and Hamilton 2021). Amongst other risks, this can entrench a mode of militarised and coercive conservation through the vehicle of surveillance, or 'conservation by fear' (Adams 2017; 2018; see also Duffy 2000; Humle et al. 2014; Sandbrook et al. 2021; Simlai and Sandbrook 2021). In addition, without adequate governance frameworks, openly accessible animal location data "can help people locate, disturb, capture, harm or kill tagged animals," with some hunters tracking data for these purposes (Cooke et al. 2017, 1205). Attending to novel modes of digital entanglement in environmental governance ultimately requires tracing how digital technologies intersect with, exacerbate, or lessen pre-existing inequalities and affect "ongoing decolonial struggles across the uneven landscapes of the postcolonial world" (Faxon and Kintzi 2022, np; see also Indigenous Geotags 2018).

The use of digital technologies to generate data also poses several problems. Rooted in ongoing use as a "technique of colonial power" (Hunt and Stevenson 2016, 372), the production of environmental data is integral to exclusionary processes that construct ecologies as profitable resources (see Murray Li 2014). Digital technologies can deepen existing inequalities in knowledge production and decision-making (Adams 2018; Bakker and Ritts 2018), widening the 'digital divide' or exacerbating harms to the 'digitally dispossessed' (Franklin 2021). Traditional ways of knowing ecologies, such as those embedded in Indigenous cosmologies, risk being erased or replaced as a result of remote, standardised ways of extracting data (see Belcourt 2015; TallBear 2013; Todd 2016; Watts 2013). Indeed, following Faxon and Kintzi (2022, np), future work in digital ecologies should look to provincialise "smart projects within situated histories" and to ground "smart development within existing struggles over land, labour, and livelihoods."

The concept of environmental data justice offers a powerful lens to challenge the extractive logic of environmental policies and produce fair and participatory data practices (Walker et al. 2018; Vera et al. 2019). Examples include community-based counter-mapping initiatives that use drones and aerial imagery to illuminate land grabbing and resource extraction within Indigenous territories (Radjawali and Pye 2017), and strengthen the claims of Indigenous groups "regarding specific environmental liabilities and justice issues" (Paneque-Gálvez et al. 2017, 86). Equally, organisations like the Arctic Eider Society (2021) and the Digital Indigenous Democracy platform are combining Indigenous epistemologies with earth observation, sensing, and communication technologies to promote community building and Indigenous participation in environmental governance (Young 2021). These initiatives show that digital technologies can enable progressive politics by demonstrating how, reconfigured, digital environmental governance can advance self-determination and environmental justice.

Digital ecologies: an analytical framework

We began this paper by diagnosing digital entanglement as a condition of the contemporary socioecological era. But on its own, this ambivalent diagnosis does nothing to engender a particular set of responsibilities or to advance an ethical framework fit for living well together in digitally mediated more-than-human worlds. Neither does it give researchers the toolkit with which they can understand the nuances and multiplicity of digital entanglement in specific empirical contexts. Thus, we propose digital ecologies as an analytical framework for examining what comes after digital entanglement (see

Giraud 2019). This provocation prompts us to acknowledge the complexities and messiness of entangled digital relations that condition more-than-human everyday life, and "to explore the possibilities for action amid and despite this complexity" (Giraud 2019, 2). Digital ecologies align approaches from more-than-human geography, digital geography, political ecology, and media studies, developing three key themes to guide future research in this emerging field: materialities, encounters, and governance. Our tripartite structure elucidates what digital entanglement entails; where it takes place and within what political economies; and who and what assemblages are implicated in the emerging forms of digital environmental governance it engenders. In conclusion, we reflect on the consequences of this approach and identify avenues for future research.

A focus on the materialities of digital entanglement highlights the implications of digital technologies and practices in economies of extraction, often involving exploitative labour relations and destructive environmental practices. Indeed, the digital technologies used to understand the effects of climate change and to study the ecological effects of mining rare earth minerals are somewhat ironically built using these very same minerals and are powered by the fossil fuels that are driving climate change (Allard and Monnin 2022). From this position, how is it possible—ethically and politically—to find hope for digital conviviality? What is clear amidst this complexity is that these are 'compromised times' where notions of 'purity' must be abandoned (Shotwell 2016). Nevertheless, it is possible to counter concepts that problematically obscure the materiality of digital mediation via metaphors such as 'the cloud'. For instance, Dustin Edwards (2020, 59) develops a creative approach—'storying digital damage'—for raising awareness of these obscured digital materialities without completely disregarding the benefits they engender. An example of one such interruptive narrative is *Phone Story*, a videogame played on mobile phones involving "a series of events that highlight ecological impacts associated with mobile phones," before the player is told: "Don't pretend you are not complicit" (Taffel 2019, 202). What is at stake, then, is understanding how digital technologies can "go beyond just raising awareness," and instead empower users to take action (Taffel 2019, 204).

Digital entanglement is not only material, but also experiential. Most humans now sense and make sense of the nonhuman world via a degree of digital mediation. Digital devices facilitate more-than-human encounters from research to entertainment, and newly-designed technologies continually emerge, opening up evermore modes of relation. As a result, experiences of digital entanglement are plural and diverse. We showed that digital encounters engender embodied and affective relations with nonhumans previously encountered without digitisation, as well as entirely novel natures made encounterable by digital technologies. These encounters should be taken seriously to understand how nature comes to be known by vast swathes of people in the contemporary era. Much existing research on digital entanglement focuses on social media, remaining rooted in representation and critical analytic lenses of surveillance and commodification which, we argue, do not capture the diverse affects involved in digital encounters. Much can be learned here from digital geographers who have developed methods for studying geographies produced through, produced by, and of the digital (Ash et al. 2018). Despite digital divides and their implicated power relations, fieldwork in postcolonial and Global South contexts is particularly important to counteract the "problematic filtering that occurs through the technological gaze" (, 324). Indeed, digitisation of environments and species is not an evenly distributed process, and attending to its plurality is essential for understanding its potentials.

Questions remain as to how to bring together the material and experiential aspects of digital entanglement into cogent analyses. While we begin the conversation here, closer engagement between geography and new media studies will offer fruitful avenues for thinking materialities and encounters—or infrastructure and experience—together. Taffel's (2019) work, which draws on Félix Guattari's entangled ecologies of mind, society, and environment offers a fruitful place to start. Taffel (2019) argues for a relational approach to scale that acknowledges how Guattari's 'three ecologies' are now always implicated in processes of digital mediation. Indeed, for Taffel (2019), it is impossible to understand the agencies of content, software, and hardware in isolation from one another.

Importantly, digital entanglement produces forms of biopower that enrol individual nonhumans and ecologies into environmental governance in novel ways. We draw attention to such instances in elaborating our analytical framework to consider how best to govern these emerging technologies which inaugurate a host of underexplored ethical challenges concerning human and nonhuman life. A focus on governance thus enriches concerns with materiality and encounter, where thinking across spatial and temporal scales is paramount, from materials to individuals to species to experience. Regarding the modalities of biopower made possible by digital entanglement, digitisation presents opportunities for activists, researchers, designers, artists, and others seeking to refashion how environmental governance takes place and subvert technocratic hegemony. Whilst digital technologies remain rooted in systems of extractive capitalism that entrench socioecological inequalities, they are not, however, bound to them: they present opportunities, not a silver bullet (Taffel 2019; Wagner et al. 2022). Digital ecologies present an analytical framework to examine and highlight subversive and novel modes of digital environmental governance.

Throughout this paper, we do not paint a purely affirmative or negative critique of digital entanglement: the same technologies which enable ethically questionable practices of digital capture, monitoring, control, and commodification incubate potentials for producing convivial futures. What matters, then, is how digital ecologies are mobilised in search of progressive ethics and political potential. As ethics are always situated and emergent (see Gerlach 2020), geographers should pay close attention to ecologists, policymakers, and other practitioners experimenting with digital technologies to determine the responsibilities and obligations they inaugurate (see Stengers 2010). Looking towards an ethical framework for digital ecologies, we pose the following question to researchers and practitioners: given the potential for digital technologies to exacerbate societal inequalities, how can they be deployed or reoriented towards politically and ecologically just futures?

In closing, we see opportunities for future work to explore how geographers can deploy digital methods themselves, developing digital ecologies in practice—meaning methods appropriate for studying digital human-nonhuman relations, as well as methods that themselves involve digital devices and practices. Such experiments with modes of representation and participation will creatively cross disciplinary boundaries. Inspiration can be gleaned from scholars like Clara Mancini, who designs digital technologies for and with nonhumans to support multispecies cohabitation, collaboration, and participation (Mancini et al. 2017; North and Mancini 2016), and Jennifer Gabrys, whose *Citizen Sense* project designs air monitoring devices with citizens to democratise environmental action (Gabrys 2017; see also Urzedo et al. 2022). Digital technologies beyond the usual sensors, camera traps, and drones, as well as non-screen-based devices, also deserve closer empirical inspection. Virtual and augmented realities, in particular, are exciting fields for geographers interested in digital ecological world-making and digital environmental politics. Speculative art and design, moreover, are challenging the boundaries between digital life and organic life beyond the figure of the cyborg evoked by Haraway (1985), offering thought-provoking insights for digital ecologies research. Anicka Yi's 'In Love With The World' (2021), for instance, asks what it would feel like to share the world with machines that could live in the wild and evolve on their own,[4] while Karolina Uskakovych's (2020) 'Encyclopedia of Consequences' places mutants generated by artificial intelligence into actual landscapes to provoke questions concerning the fusion of biology and digital technologies.[5] Such projects implore researchers to examine in greater empirical and conceptual specificity the intimacies and affects that emerge during the digitisation of human-nonhuman relationships and to elucidate the positive, negative, and ambivalent aspects of digitally mediatd more-than-human worlds.

The analytical framework we outline in this paper regarding materialities, encounters, and governance serves as a guide for future research in the emerging field of digital ecologies. What, then, comes after digital entanglement?

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Notes

1. 'Digital ecology' was already in existence among landscape ecologists who use it to denote monitoring techniques, information practices, and modelling capacities in the digital age (Green et al. 2006). In 2017, the Media Convergence Research Centre at Bath Spa University hosted a symposium exploring similar themes to this paper entitled 'Digital Ecologies and the Anthropocene'. Morey (2012) uses 'digital' as a metaphor to rethink 'ecology' in his chapter entitled 'Digital Ecologies'. Sy Taffel (2016) uses the term 'digital ecologies' in the title of a book chapter, although not in the chapter itself.
2. See https://twitter.com/awitnesstree (@awitnesstree) and https://www.facebook.com/awitnesstree/. The Harvard Forest Witness Tree project Tweets and

posts on Facebook about its changing environment using an array of sensors and a custom-built computer program. More information can be found here: https://harvardforest.fas.harvard.edu/witness-tree-social-media-project.
3. Here, we focus on recent iterations of 'media ecologies'. For an excellent genealogy of the use of 'ecology' as a metaphor for understanding mediation, see Treré and Mattoni (2015) and Treré (2020).
4. Anicka Yi's installation populated the Turbine Hall in London's *Tate Modern* from October 2021-February 2022: https://www.tate.org.uk/whats-on/tate-modern/exhibition/hyundai-commission-anicka-yi.
5. Karolina Uskakovych's work is a "speculative design experiment in loving our monsters": https://encyclopediaofconsequences.art/.

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16. Hiding (in) the Tall Grass: Rethinking Background Assets in Video Game Plantscapes

Merlin Seller

Abstract

This chapter explores the significance of "grass" assets, bringing critical plant studies and the Anglo-American lawn's cultural historiography to textual analysis of ludic backdrops. While Alenda Chang critiques the functionally inert plants of predominantly visual video game environments, this risks reinforcing the treatment of plants in purely instrumental "functional" terms and repeating what Michael Marder identifies as Western marginalization of flora's rooted, headless alterity, and reifying narrow anthropocentric values of agency and centrality. Indeed, passivity is key to video games, and game studies regrettably marginalize visuality. I propose that questionably "visual" and "inert" background assets (exemplified by grass) offer rich and underexamined terrain for analysis wherein the "plantscapes" dwarfing humanity might challenge disciplinary understanding of agency/interactivity and foreground/background.

Keywords: nonhuman, plant, *The Last of Us*, *Flower*, visual studies

Seeding

> All others in the prick tale are props, ground, plot space, or prey. They don't matter; their job is to be in the way, to be overcome, to be the road, the conduit, but not the traveller, not the begetter. The last thing the hero wants to know is that his beautiful words and weapons will be worthless without a bag, a container, a net. (Haraway 2016, 118)

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Figure 16.1: "Staying crouched in the tall grass makes it more difficult for enemies to see you." Screenshot from *The Last of Us Part II* (Naughty Dog 2020).

How do we account for the visual "stuff" filling our video game screens, that flesh out worlds we jump over, that hide in plain sight? How might we give an account of the visual "container" of play without which narratives and systems would be "worthless"? Here I argue that reckoning with digital grass exposes environmental assets' power and the strange verges of interactivity and perception. As Alenda Chang observes, plants in video games are "simultaneously hypervisible and invisible, ubiquitous enough to pass beneath notice" (2019b, 123). Grass demarcates zones of stealth for players in games such as *The Last of Us Part II* (Naughty Dog 2020) (see Figure 16.1) and, conversely, is an asset so ubiquitous as to escape our attention. Their omnipresent marginality makes them an exemplar "last thing the [player] wants to know" (Haraway 2016, 118). I explore the ontological and cultural significance of "grass" assets, bringing critical plant studies (Hall 2011; Marder 2013; Pollan 2001) and the Anglo-American lawn's cultural historiography (Marusek 2012; Robbins 2007; Steinberg 2006) to the visual analysis of recent American video game backdrops. Where game studies regrettably marginalizes visuality (Keogh 2018; Murray 2017), I argue that props aren't simply set dressing, but forces, historical traces, and powerful atmospheric devices. Questionably "inert" background assets, exemplified by grass, offer rich terrain for analysis where "plantscapes" dwarfing humanity (Hall 2011, 3) might press upon disciplinary understandings of agency and representation. I'm specifically interested in how grass populates video games which don't frame themselves as "grass" video games, but which are nonetheless saturated with it. While it would be straightforward to critique video game designs for lacking accuracy or dynamism, such as failing to simulate tiller-derived daughter plants or the distinction between Chamisso sedge and Roemer's fescue, I am more interested in what digital grass *does*: how we might "think with plants" (Meeker and Szabari 2019, 14). I focus on nonagricultural turfgrasses, to tackle the ornamental grasses we're most familiar with and the grass left out by farming/terraforming sim analyses, and within this scope I aim to clear openings for plant thinking rather than a synoptic account. First this chapter introduces digital grass through a short survey of examples, before turning to the key discursive claims of this text in a focused literature review on plants and landscapes in games. It concludes with two "verge" cases of unexpected flourishing in American ruins.

The digital playing field: Locating video game grass

Western Anglophonic societies discipline grass but are also disciplined *by* grass—grass turns us into grass subjects through its physical wants and metonymic symbolism of social (dis)order (Robbins 2007). Grass is thus both a material and discursive entity imbricated with humanity. Arguably, video game grasses are only as artificial as real-world lawns, even when video game grasses vary from simple textures to sprites, shaders, or models. Like the chemically intensive grass of a golf course, kept on life support at an eighth of an inch (Steinberg 2006), video game grass is both computationally expensive and much closer to a planar background than bespoke "hero props," such as a gnarled oak. Yet turfgrass cultivation, accelerated by the spread of sports fields in the mid-twentieth century, is entangled with the history of play. Grass representations can speak to what Virginia Scott Jenkins (1994) and Ted Steinberg (2006) call the American "obsession" with the lawn as planar monoculture reinforcing the social conformity of White suburbia. Lawns also constitute North America's most cultivated plant, covering an area larger than Florida, and represent a chronic ecological disaster in the flows of oil, water, fertilizer, herbicides, and non-native species (Steinberg 2006, 4–5). American lawn aesthetics are clearly expressed in *Lawn Mowing Simulator* (Skyhook Games 2021), which focuses its simulation on the apparatus, but fills our view with cutting lush green down to anemic stubble. The regimented lawn, much like the playing fields of video games such as *Madden NFL 22* (EA Tiburon 2021) and *PGA Tour 2K21* (HB Studios 2020), flattens physical space to something approximating abstract digital space: a disciplined, regular, cartesian plane of predictable affordances and minimal friction. Indeed, physical turf is itself a problematic cyborg assemblage, existing at the intersection of chemistries, plant bodies, and machinery—it can be deployed as a ready-made mulch of soil and seeds from a hose, or machine-cut to the point of fertilizer spray dependency.

This form of grass represents a literal flattening of ecological feedback loops in Timothy Morton's (2016) sense, contorting ecology into anthropocentric rational order. In the trajectory towards a zero point or ground, lawns in video games can evince a similar kind of techno-primitivism to what Irene Chien identifies in *Journey* (thatgamecompany 2012), using W. J. T. Mitchell's (2002) double-temporality of the featureless desert as a kind of blank slate in Western thought: both origin and utopian endpoint, embedding the "mathematical in the natural" (Chien 2017, 144). Digital grasses are cut close to their real-world counterparts, like Jonathan Cane identifies in a different postcolonial context, South Africa: "The lawn attempts to dematerialise itself, or deny its own materiality—as if it were not made out of living matter, as if there is no labour and no consequences to lawning a space" (2019, 174).

This dematerialization is incomplete, and while it resonates with our "plant blindness" (Wandersee and Schussler 2001), it also exposes plants' passive resistance to repression. Grass is conventionally the most omnipresent and strangely invisible of plants in video games. We see this in survival video games where nearly every plant can be bent to the colonial will of the Robinson Crusoe-like player *except* for grass—a resource too ubiquitous and too mundane to model as a resource in video games such as *The Forest* (Endnight Games 2018) and *Rust* (Facepunch Studios, Double Eleven 2013). This grass underfoot tells the lie to the extractive agrilogistic gaze of the player for whom a survivalist setting of scarcity does not permit consideration of how life flourishes in an "inhospitable" setting. Grass in this sense threatens the colonial player gaze, shadowing us with what Michael Marder calls plant growth beyond "rational" reason (2013, 182). The inflationary extension of plants towards their Other exceeds the quantifying resource management of many games, rendering grass "invisible." Complementarily, ungraspable grass is also the condition *of* "invisibility" for nonhuman animals in games like *Pokémon Red* (Game Freak 1996) and for the player in stealth action games such as *Assassin's Creed: Valhalla* (Ubisoft Montreal 2020). Exemplary of grass' two-sided ubiquitous marginality is *Plants vs Zombies* (PopCap Games 2009), where grass is not a centered "plant," but their diffuse backdrop, hypermarginal. Only very occasionally do grasses join the "parliament of things" as a critter that moves, as seen in *Everything*'s (David O'Reilly 2017) utopian inter-scalar play of dancing assets which applies the same verbs and subject status to every object in its universe. However, as I will argue with my concluding case studies, video games of ruined anthropogenic landscapes can render explicit the fact that the disciplining of grass is ambivalent, “never finished and will always be tenuous” (Cane 2019, 177). It is from the verges that grass exerts its power as a container.

Hiding in the undergrowth

To articulate this ambivalent and unfinished “container” of play, we need to engage with the literature concerning video game plants and landscapes. Playing fields and lawns haunt game studies: Mihály Csíkszentmihályi lamented social limits to flow in 1969 through vegetal metaphor arguing “grass can grow in even the cracks of a concrete pavement—but an open field is still something else” (cited in Soderman 2021, 241); Ian Bogost centers *Play Anything* on struggling to make his lawn grow through chemical treatments as an example of how “anything” can become play (2016), despite the brown grass he seeks to eliminate being perfectly healthy (Steinberg 2006, 76). While here grass primarily signifies constraint for play without being considered in its own terms, it also holds implicit agency, force, and resistance.

Grasslands cover 40 percent of Earth’s land (Wang et al. 2019), and lawns cover 23 percent of urban space in the US (Robbins and Birkenholtz 2003), yet unlike trees, which are giants of both the plant world and critical plant studies, grasses are trodden underfoot. As Owain Jones and Paul Cloke argue, trees take up more cultural space than grass and are contrastingly capable of appreciation as “individuals” (2002, 29), whereas smaller flowering plants have less cultural traction in the West because they are falsely assumed to have little impact on landscape or economy (Mabey 1996, 71). However, as Robin Wall Kimmerer notes, grasses are embedded in social relations and deserving of respect as beings (2013). Matthew Hall (2011) and Marder (2011, 2013) encourage us to think with *all* plants, and the thorny metaphysical and ontological implications of plants’ alterity. Grasses experience time differently, responsive in nonhuman rhythms to contexts such as the seasons (Marder 2013); they exist without the distinction of center and periphery as diffuse middles without heads (Marder 2011), and while seemingly passive, eventually plants will consume us all (Keetley and Tenga 2016, 19). They create the atmosphere and so brush against our lungs even when we cannot see them—they are thus both intimately familiar to us and present as codesigners of even the most “unnatural” environments (Coccia 2018, 50). In approaching these everyday aliens, we might question our values and oppositions of center/margin, foreground/background and interactivity/passivity.

Chang's excellent work on virtual plant morphology in video game development provides a framework for beginning analysis of plant assets themselves: the complexities (or reductive abstraction) of modeling trees (2019a). As Chang argues, we might value representation in terms of responsiveness to context—contrasting "narrow realism" of static assets with a pipeline that incorporates forms of environmental process in the procedural generation of plants (2019a, 11). Grasses have experienced more limited investment compared to the trees Chang charts, often quickly produced as either flat textures, repeated alpha planes, or simple tapered and flattened 3D primitives grouped in clusters; over 1,100 assets from packs of shaders are cheaply available from the Unity asset store at the time of writing, indicative of their low-cost profusion. These assets are often built from reference photographs, but repetitively modular, absent roots, and often lacking stems or tillers, atomizing grass to individual leaves. However, the subterranean portion of the plant, half its mass, is ordinarily invisible to humans just as their internal chemistry is opaque and their rhythms imperceptibly slow; our awareness of plants is always partial. Nevertheless, rather than simply dematerialized, digital grasses still possess "digital materiality" which Yuk Hui ascribes to things such as images and models, which they see as possessing tangible affordances embodied in sets of relations such that "digital objects" are not static representations, but temporal entities experienced phenomenally: "digital objects don't obliterate experience, but they do modify meanings" (2016, 205). As Chang concludes, we need to reckon with the vegetal forms that inhabit games, pushing for the texture of ecological/sociohistorical realism over impressionistic "photorealism" but also respecting that design research affords digital plants a referentiality and materiality: "somewhere between soil and sky, computer and cloud" (2019a, 12).

A core critique of plant representations stresses the problem of reducing plants to scenic backdrop. "Backgrounding" (Hall 2011; Haraway 2004) appears to portray beings as passive and inert by rendering them peripheral. Within game studies, Chang similarly critiques "functionally inert" plants in "predominantly visual" video game environments (2019b, 23). However, this argument risks reifying the treatment of plants in purely instrumental "functional" terms and repeats what Marder identifies as Western devaluation of flora's rooted, acephalic alterity (2013). It arguably underestimates the ubiquitously invisible power of plant monocultures subtending society (Pollan 2001; Steinberg 2006) and reinforces anthropocentric values of agency and centrality. Indeed, passivity, while underappreciated, is fundamental to video games, which often consists in waiting, watching, delegating, enduring, and reflecting (Fizek 2018; Keogh 2019), and while Chang's critique encourages a broader spectrum of potential systems, it risks ignoring the significance of visual representation in a visual medium. Similarly, in discussing video game landscapes, Eric Hayot and Edward Wesp imply an anxiety about the visual in their object of study, stressing video games are "not merely a picture of a world—the visual surfaces of its objects" (2009). But the assumption that graphics are "superficial" reflects a wider dynamic in the humanities whereby surfaces are misconstrued as incidental or frivolous whereas in actuality they offer rich material for analysis (Anusas and Simonetti 2020, 1). Backgrounds, textures, and set dressing are meaningful: rather than secondary, surfaces are the "first and primary face of being" (Amato 2013, 1), the material of our experience.

In the context of game studies' preference for systems and narratives, and disregard for visuality (Keogh 2018), "backgrounding" critiques can be read as reinforcing the foreground/background interactive/passive hierarchical distinctions of both game studies' textual analysis approaches and wider anthropocentrism. It fails, as it were, to see the grass for the meadow. Indeed, prioritizing "foreground" and "action" implicitly devalues plant being: a plant may well not have a sense of centrality, self, or agency when it shares resources with unrelated partners through a fungal network (Sheldrake 2020, 138) or extends itself to the point of collapse (Marder 2013, 73–74). As Marder has it: "colloquial and philosophical discourses associate the rooted mode of being with immobility and captivity" (2013, 12).

To concur with Chang's (2019b) wider argument drawing on Emma Marris (2011), perhaps video games are messy, rambunctious gardens. However, I would raise the possibility that video games don't have to change their representations of plants as much as we need to change our approach to respecting the troublesome flourishing of life in a world with no pristine state. We might learn as players and scholars to question our priorities and learn to see the verges of the visual field. Much as Seth Giddings and Helen Kennedy frame play, reckoning with environmental assets in mainstream video games necessitates we recognize "activity and passivity are not opposites in videogame play but fluctuations in the circuit" (2008, 30). The study of digital grass, then, might contribute to critiques of a privileging of interactivity (narrowly defined) in games (Keogh 2019; Fizek 2018) and the growing discourse on games' visuality from Soraya Murray (2017), TreaAndrea Russworm (2017), Irene Chien (2017), and others. Significantly, hiding in the grass of *PUBG: Battlegrounds* (PUBG Studios 2017) offers Brendan

Keogh (2018) a prime example of how player passivity is prevalent in games we consider "active."

Rather than speaking of "background" and the ambiguous hierarchy it implies, we might more productively speak of game environments as landscapes, contributing to scholarship on the video game sublime (Martin 2011; Vella 2015) with rather more mundane encounters with alterity. Grass is enmeshed with landscape: it both builds landscape by cohering soil and deconstructing CO_2 and is shaped by the dynamics of space, light and water. In video games, grass coats levels, repeated low-poly assets that give substance and texture to player wanderings. Tim Ingold (1993) argues, as substantiated by Marris (2011), that landscape does not precede alteration by human presence and, like video game level design, it constitutes an anthropogenic "taskscape" (Ingold 1993, 153–155). In Ingold's analysis, landscape/taskscape is always in a process of becoming-with other objects, "a place where several goings on become entwined" (2010, 4) perceptible as traces. Similar to Mitchell's (2002) understanding of "landscape" as a verb—rather than simply a passive object acted on—with Ingold we might explore video game landscapes as traces of dynamic process articulating more-than-human activity in a mess that enfolds us, even if landscapes may appear static on a human temporal scale. Thus, if the technologically inflected pastoralism of *FarmVille* (Zynga 2009) suppresses and abstracts a sense of ecological history into the clean, flat territory of atemporal agrilogistics (Chang 2012), in video games where there are noninstrumentalized grassy verges, we might still find rich places where "the individual player can experience the game space as a place for dwelling rather than merely a territory" (Nitsche 2008, 193).

This allows us to begin reframing power dynamics borne out by the taskscape "container" of human–grass relationships. Michael Pollan asks us to consider that perhaps plants are farming us, as from the perspective of a monoculture humans are excellent propagators (2001), with Paul Robbins going so far as to argue grass exacts tyranny over its "turfgrass subjects" (2007, xvi). The lawn of *Lawn Mowing Simulator* "wants" in Robbins' (2007) and Mitchell's (2002) sense: not just that they lack but that they demand inputs. Indeed, as Richard Mabey sees exemplified by weeds, plants' autonomy from humanity and necessity for our survival means they subtly refuse subordinate status—plants and humans coflourish as partners. "Although they follow and are dependent on human activities, their cussedness and refusal to play by our rules makes them subversive" (2011, 20). Grass doesn't need us nor cares about us, something an anthropocentric perspective avoids acknowledging, but which video games can highlight in their weedy recomposition of space. It troubles our understanding of agency and definition of "passive" when the seemingly "functionally inert" applies pressure by conveying depth of time or conditioning player roles as hunters or gardeners: "As the background within which a figure, form, or narrative act emerges, landscape exerts a passive force of setting, scene, and sight" (Mitchell 2002, vii).

In the second half of this chapter, I turn to case studies of video game grass in the ruined American landscape that put pressure on relations of power and the borders of interactive/passive, background/foreground, and lawn/weed, troubling ontological and sociohistorical hierarchies and relationships. The taskscape that is the "container" of play is exposed in the "civilizing lawn" (Cane 2019) and its failure as something which suffuses our experience of *The Last of Us Part II* and *Flower* (thatgamecompany 2009).

The Last of Us Part 2: Revenge of the lawn

I press my body close to the earth, prone, concealed by short tillers that bend before me as I push up into a crouch and weave among taller leaves. I'm hunting humans and fungal zombies in *The Last of Us Part II* (hereafter *TLoU2*), who I drag remorselessly into the rampant green of a suburb decades after the fall of one world and the blooming of another. Here we have a dark rewilding, the post-lawn grass assets of a zombie apocalypse suburb—*TLoU2*'s Hillcrest environment.

Lawns, Steinberg (2006) argues, stabilize social identity and property, and they spread with American highway and car culture—technologies enabling suburbs but paradoxically rendering their imagined pedestrian communities obsolete. The lawn, therefore, is irrational growth, an empty, costly, monocultural expression of social conformity. Indeed, lawns are hauntologous—the hollow echo of neighborhood communities that never came to pass. But the rusted car culture of postcollapse *TLoU2* forces us to squirm our way through the undergrowth. Grass problematizes the passive/interactive binary, both by registering different temporalities and by being a background that determines stealth mechanics (see Figure 16.1). As Robbins' concludes of real-world turfgrasses: "[I]t is their rules that set the pace and character of subjected lives" (2007, 135).

Scholarship on this franchise offers readings of the series' intense human–human violence as "ludo-narrative dissonance" (Hughes 2015). Critically, Russworm has also deconstructed the prequel's token representations of race as secondary and sacrificial (2017, 112). Yet, as incisive and necessary as these analyses are of the games' human dramas, scholarship on the franchise has largely avoided discussion of the fundamental nonhuman actants of this world. As Anna Tsing has argued, we need to expand our sense of interrelation to appreciate more-than-human temporalities (2015, 5), and *TLoU2*'s huge vistas of dilapidated cities-turned-meadows encourage critical readings of historical progress. Players are stuck in a world of ruin that continues blooming without them. Conversely, focusing on character dramas and animals traps us "in a tiny prison of our own devising, one in which all that concerns us are the fleshy beings that are our kindred" (Bogost 2012, 3).

Grass assets in expansive level designs have us regularly observe enemies from the grass, the interface drawing attention to the edges of the screen and the space between bodies through highlights and audio cues: we are reminded of intervening time and space, that this is a world in which animals are a footnote to the visually omnipresent victory of grass. Mastered by flora, *TLoU2*'s landscape facilitates player reflection on the inescapability of Haraway's "container" (2016, 118) and more-than-human ecology as speculative visual "mesocosm" (Chang 2019b, 11). Seattle's posthuman biosphere here represents how the vegetal world might recompose urban materiality, rather than being dematerialized into a lawn. Grassy motorways channel aesthetic contemplation onto disturbed boundary zones and the messy anthropogenic character of our biosphere (Ellis 2015). Thus, in our rhythm of waiting, watching, hiding, springing, dragging, and sliding through desperate arenas where animal life clings on to a plant world outgrowing us, we experience being messily enfolded in a taskscape.

Indeed, Earth is a "plantscape," a biosphere dominated by plant life in relation to which animal biomass is marginal (Hall 2011, 3), a reality exposed by *TLoU2*'s visuality. Here the Anthropocene horror of vegetal revenge stems from the repressed knowledge that we are all food for flora in death (Keetley and Tenga 2016, 1). As Morton argues, ecological thinking across temporal and spatial scales, from meadow grasses to blades in the cracked concrete, highlights the ways our conventional sense of "world" has already ended and necessitates that we realize there is no "elsewhere" (Morton 2016, 160): every background is someone's foreground. By expanding our attention we might practice Tsing's "arts of noticing" (2015, 17) and find marginal life by learning "to watch out of the corner of your eye" (Kimmerer 2003, 9).

Furthermore, combining Tsing's observation of the unintentional, more-than-human "design" of real-world landscape (2015, 15) with Chang's assertion that game systems and aesthetics "straddle multiply real and imagined worlds" (2019b, 11), we might appreciate the materiality and richness of *TLoU2*'s landscape. Grass entrains environment artists in plant thinking both by being present in design as reference material, and by being speculatively anticipated by asset artists (more than seventy of whom specialized in *TLoU2*'s environments) who are increasingly interested in visual aspects of trace, growth, and wear as features of modeling, texturing, and rendering. Attention is paid to sources of light, the decomposition of substrata, and the spread of grass by seed and rhizome through cracks in Csíkszentmihályi's concrete. As the director notes, the local ecology of Seattle was drawn on throughout preproduction and production (Druckmann 2020) of scenes stressing the resurgence of plant life unchecked. With dark uncanniness, *TLoU2*'s Hillcrest is largely a monstrous suburban monoculture, the ghost of the lawn haunting us with a lost past and a flourishing, inhospitable present. What survives the final render is a weed: plants which "obstruct our plans, or our tidy maps of the world" (Mabey 2011, 1).

Scholarship's tendency to treat visual assets in games as superficial or invisible, dismisses popular and trade press fascination with "graphics," as well as failing to adequately reflect both their substantive screen space and production resources. As Nataska Statham et al. note, blockbuster titles such as *TLoU2* regularly utilize scanned textures and geometry composed from computationally processing multiple photographs to create the basis of models: photogrammetry (2020, 12). This is deployed alongside complex physics-based rendering and context-dependent animation, the latter here resulting in grass that bends around and obscures player movement. Transplanted into artificial space, assets are a weedlike "plant out of place" (Mabey 2011, 8), but like weeds they thrive around us. By enfolding indices of flora through referential and procedural processes, *TLoU2* therefore facilitates rich aesthetic engagement with the taskscape of its "container." To ignore this production would repeat Western society's "plant blindness" (Wandersee and Schussler 2001), where plants constitute "the thing we can't or won't see" (Keetley and Tenga 2016, 8), problematizing our conception of agency through modes of repetition and slowness (Marder 2013). We might instead marvel at how aliens are "everywhere" (Bogost 2012, 133). *TLoU2*'s postapocalyptic fiction highlights both the anthropogenic roots of our physical landscapes, and the powerful codesign/coconstructive effects of nonhuman actors to shape our video games and thrive in our wake: both passive and (inter)active, everywhere and out of place, a background inextricable from foreground.

Flower: Grass atmospherics

I'm tilting my console, wafting plants through a meadow to revitalize environments filled with human ruins and spacious fields. The experience

Figure 16.2: A screenshot from the game *Flower*.

is one of rhythmic color pulsing with green in each encounter, skeins of abstracted air currents flicking around topography, and spiraling flecks of rainbow hues atop hills of grass. Holding any button, wind courses forwards and swerves as I bend myself and the PlayStation Vita to pour petals over leaves. This is *Flower* (see Figure 16.2). Released in the same year as *Plants vs Zombies*, Jenova Chen's *Flower* posed a denser ecomimesis of lively grass. Onscreen 200,000 blades are rendered simultaneously (Athab 2009), all obliquely "interacting" with the player, who embodies an atmospheric force traced in plants: wind bending grass. While *Flower* does make plants central, it is more meaningfully concerned with the grass of its backdrop than the few thousand flowers of its foreground.

This meadow may imply Csíkszentmihályi's image of seamless autotelic flourishing given Chen's (2007) interest in "flow," an affect whose lack of criticality has been critiqued by Braxton Soderman (2021) and Keogh (2018), but loose controls disrupt movement mechanics. We listlessly eddy outside of flow as much as being channeled through its valleys, a large turning radius forces us to loop and rest between blades of grass in contemplative moments of "dwelling" in Ingold (1993, 1) and Michael Nitsche's (2008, 192) sense, rather than domination. Indeed, Chang laud's *Flower*'s capacity to involve us environmentally, but we might invert her emphasis on "mechanics" over "graphics" (2019b, 31) because *Flower* visually articulates the atmosphere plants engineer (Coccia 2018) as codesigners exerting passive force as a landscape.

The postphenomenology of atmospheres (Böhme 1993; Griffero 2014), can aid in the arts of noticing and expand our awareness of video game containers. Postphenomenology responds to phenomenology with “a move away from a subject-centered approach to experience” (Ash and Simpson 2016, 53) and, through atmospherics, we can appreciate these more-than-human experiential spaces affectively and aesthetically. The “staging” of materials (Böhme 2013), here through grass assets, animation, and postprocessing, creates “quasi-objective” affects from the relation of subject and object (1993, 69). This can be thought of as a form of harmony integrating the partly objective, partly subjective nature of play as we become with grass. Tonino Griffero casts such moments of encounter with the Other through a felt atmosphere as “pathic aesthetics” in which appearances “resound in the lived body” (2014, 7). Indeed, this is how we perceive the world, continually accessing surfaces and affects rather than interiors and objective truths. As Aubrey Anable has it, “video games are affective systems” (2018, xii). In this sense, *Flower* does not represent the dematerialized lawn or authentic meadow, but rather the weedy experience of everyday reality as quasi-objective and aesthetic.

For Gernot Böhme, atmospheric materiality is the experience of enmeshed bodies, both physical and virtual, and sensing is itself an interactive process he calls “felt space” (2017, 92), neither purely passive nor inert. I argue video game landscapes are atmospheric fields of what Böhme would see as affective apprehensions (1995), where we can move beyond ourselves (2017) in more-than-human understanding. Here players bend with, through and as the wind, connecting plants in the atmosphere produced, billowing beyond ourselves in “ecstasies,… ways of stepping outside of oneself” (Böhme 2017, 163).

While *Flower* may beautify its Californian setting with smooth low-poly models and soft color gradients, we should be careful not to dismiss the aesthetic which Morton sees as a key mode of ecological awareness (2016), in a medium Keogh powerfully argues is primarily tangible for players as “audio-visual-haptic” sensations (2018, 17). Indeed, from the perspective of both botanical science and situated First Nation knowledge, Kimmerer stresses the importance of beauty in both seeing and conceptualizing plant relationships she figures as a synergistic color complementary (2013, 45). These permeate *Flower*—red-green and yellow-purple—and for Kimmerer this visuality encourages an ethics of reciprocity (2013, ix–x). In *Flower* we feel something of this atmospherically. If Kimmerer’s issue with Western science is that it is a “language of objects,” where First Nation knowledge is a language of animated interrelation (2013, 49), *Flower* is nothing if not the latter—rhythms restoring vivacious color to progressively urban ecological ruins by circulating petals through grass in explosions of green (see Figure 16.2). As a breeze, we hug the earth, but only have presence as displacement in the depression of airbrushed fronds or the lazy helix of petals hanging as a pulsing gestural composition. Indeed, the player-as-atmosphere effaces themselves, dispersing petals to make way for the verdant grass, which cascades hues in a rhizomatic ripple. This is not as much a game of tangible cause and effect, much less lawn maintenance, but it is a game of weedy self-sufficiency and the reframing of urban ecology. As if articulating *TLoU2*'s rewilding, here the city is cast as a plant's postapocalypse, and our task is to reframe ecosystems through atmospherics. As much action as perception, as much foreground as background, we brush the contours of a landscape. In touching the grassy "container" and feeling it ripple through screen and controller gyro, we turn bodily and virtually with and through grass as an atmospheric force of the landscape, "brush[ing] upon the edges of their being, which is altogether outer and exposed, and in so doing to grow past the fictitious shells of our identity" (Marder 2013, 13). Doing so we operate playfully in the verges between seeing an asset and interacting with it, where, like Morton's ecological model: "there flickers a dark pathway between causality and the aesthetic dimension, between doing and appearing" (2016, 5).

Reaping

Having considered cultural-historical and ontological contexts—haunting and rippling lawns, weeds and meadows—we can appreciate that humans condition, and are conditioned *by*, grass. Grass is both a social allegory of discipline and weedy resistance, but as an asset it also causes trouble ontologically and disciplinarily for our assumptions concerning agency, interactivity, and superficiality.

Grasses are a margin that thrive in disturbance: both where we aren't looking, and where we look without seeing. As such, progressive representation of grasses need not apply human values of centrality and foreground to diffuse and profuse beings but might trouble us from ubiquitous margins. On the edges of interactivity, the grassy verge haunts "between doing and appearing" (Morton 2016, 5). Proliferating between visible and invisible, interactive and passive, grass permeates a visual field that requires us to look, feel, and notice these atmospheres. In postapocalyptic landscapes, with their rich aesthetics, environmental storytelling, and atmospherics, I argue there is in fact a rambunctious aesthetic fulfillment of Chang's imperative that "we need game environments that respond to human agency and yet seem to possess life independent of player actions" (2012, 251). Perhaps, fundamentally, we should respect that grass might not care how we represent it. It problematizes our own sense of centrality by thriving with and without us, "troubl[ing] the traditional distinction between the respectable and the merely utilizable" (Marder 2013, 110).

Ludography

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Stefan Schöberlein

Garden Warfare – Videogaming's Green Thumb

Gardens and videogames make for strange bedfellows – and are thus ripe for a good joke. An episode of the ever-expansive *The Simpsons* perhaps put it best: its 1998 season sees the sibling pair of Bart and Lisa struggling with taking care of the family's back garden, a task apparently so out of synch with their own enjoyment- and consumption-centered lifestyles that even forgoing their monthly allowance becomes preferable to keeping the yard in order. A seemingly much too strenuous, tedious, and even archaic scenario – their little yard outfits earn them laughter from the neighborhood bully – gardening just cannot compete with the constant stream of entertainment provided by TV or the momentary thrills of a carnival visiting town. The latter, ironically enough, brings with it a "Yard Work Simulator," a Virtual Reality videogame that makes these children long to perform in an artificial game environment what they had previously refused to do in real life (see figure 1).

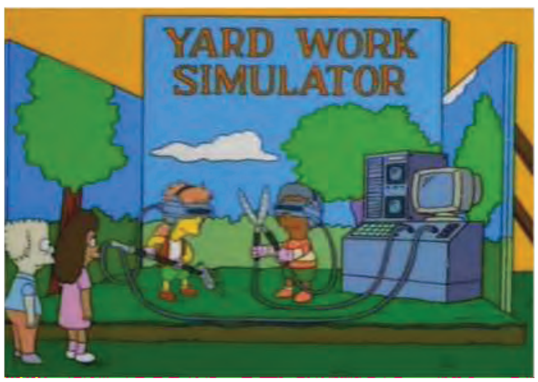

Figure 1: Yard Work Simulator (Kirkland 1998, 03:00).

This joke, of course, is not a new one. Even in the words of someone like Ralph Waldo Emerson, the sentiment of the Simpson children would have found an ally, with the celebrated transcendentalist, later in life, calling "pottering in a few square yards of garden" utterly "dispiriting and driveling" and arguing that gardening and sustained intellectual pursuits are "antagonistic [forces], like resinous and vitreous electricity" (1860, 100). Gardening and videogaming, it appears, are a quite discordant pairing, the former relishing in slow, manual labor and often generating a feeling of meditative relaxation in its practitioners (cf. Nakau et al. 2013), while the latter takes delight in spectacle, discloses at least hints of competitiveness, and necessitates, as N. Katherine Hayles has called it, bursts of "hyper attention" (2007, 187).

Still, besides the intuitive notion of an incompatibility between these two worlds, reality has slowly rendered the *Simpsons*-joke mute: games like *Potioneer: The VR* [Virtual Reality] *Gardening Simulator* (Focus on Fun Games 2016)*, Garden Simulator* (Focus on Fun Games 2010), or *Bonsai Growth Simulator* (Wade 2016) have turned what was a preposterous proposition in the late 1990s into a real-life commodity, serving a niche market dealing in life-simulating videogames. In essence, *Yard Work Simulator* has become a reality, and with fishing rods already available for VR setups, gardening rakes and hedge clippers cannot be far off. That games like the aforementioned are often of quite low quality and have by now even given the term "simulator" itself a rather bad name is perhaps beside the point here; even in the broader world of mainstream videogaming, the notion of "gardening" has long since become a recurring theme and, often, a gameplay mechanic. Gardens can be built in games from a variety of genres – be they online Multiplayer games like *World of Warcraft* (Blizzard Entertainment 2004)*,* strategy games like *Civilization V* (Firaxis Games 2010)*,* or so-called "sandbox" first-person experiences like *Minecraft* (Mojang 2009) – and they serve numerous gameplay purposes there.

What makes a medium like videogames a specifically telling object for gauging cultural attitudes about gardening is this core interactivity. For a garden to properly exist in a virtual world it must be operationalized by the game's creators – it has to be turned into a switch that does a specific thing when flipped in a specific way. While a garden can also serve as a backdrop in games in a manner similar to movies (one might think, for instance, of the gardens of Versailles in the game *Assassin's Creed Unity* [Ubisoft Montreal 2014] and the Mel Brook's film *History of the World* [1981]), these moments of gamification are perhaps the most telling; They force the game creators to boil down the rich tapestry of cultural history and meaning-making surrounding the space of the garden into a clear set of computational operations. This chapter thus hopes to hunt for these garden and gardening mechanics through a variety of videogame worlds to begin to understand what it means to garden digitally – and what that gardening can tell us about the West's[1] real-life fascination for enclosing and cultivating small plots of land for personal enjoyment.

What's in a Garden?

While gardening as an in-game mechanic is still rarely mentioned, a related notion – farming – has become a staple in discussions of videogames, both literally and metaphorically. As such, farming mechanics can provide a good entry point into defining gardening for a videogame context. Indeed, it is

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1 This essay will focus largely on gardening mechanics in games produced in or focusing on a broadly defined 'Western' cultural sphere, its history, cultures, and mythologies. A similar analysis of Eastern-influenced games – especially Japanese and Korean games – is still outstanding and cannot be done justice in this chapter alone. Excluded are thus Eastern games like *Final Fantasy* as well as Western games like *Shogun: Total War* set in an explicitly non-Western context (see also Pulos and Lee 2016).

farming – not gardening – that has come to describe what the *Simpsons*-joke implies: a monotonous, repetitive, manual task that is performed as a sort of digital labor to enhance or advance through the core gameplay experience.

A player might "farm" by engaging a large amount of easy enemy characters to gain enough "experience points" to be able to face tougher challenges ahead, accumulating currency to spend on certain items in digital markets, or even, say, repeatedly pressing the "jump"-button for a long time to improve his or her character's physical abilities. Some of these tasks have become so time-consuming that players have, in rare cases, even outsourced these labors to digital sweatshop-workers (see R. 2013; Graham 2010). Farming in videogames has thus taken on notions of manual labor, monetary gain, expansion, and growth. It is a thing one does to secure his or her digital avatar's place in the game world.

The same logic holds true for more literal "farming" in games. The long-running strategy game franchise *Civilization*, for instance, allows the player (in its fifth installment) to construct "farms" as well as "gardens" – with the former providing food for the civilization the player controls and the latter increasing his or her chance of generating so-called "great people" or even "happiness" itself (an in-game currency). The former is also tied to research into "Agriculture" and external to the player's cities, while a garden must be built inside of settlements and requires prior knowledge of "Theology." Farming translates, mechanically, to sustenance, and outwards growth, while gardening seems more preoccupied with leisure, meditation, and spirituality.

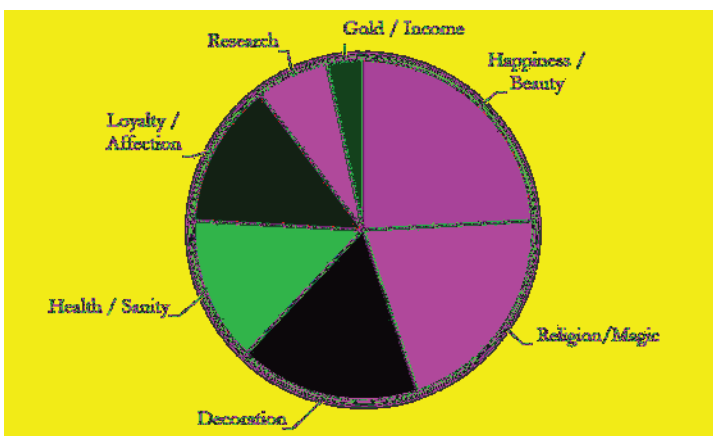

Figure 2: Effects of gardening mechanics in 18 post-2000 videogames by domain (data based on close reading). A single game can fall into multiple domains.

Just a brief look at the gardening mechanics of some post-2000s mainstream videogames (see figure 2, and figure 3 on the next page) shows that these attempt to mechanically echo the long history of the garden as a haven for the

Sublime (cf. Francis and Hester 1995, esp. 21-54, 189-259). More than a third of these games explicitly enable restorative and/or religious (magical) mechanics through their garden structures.

	Happiness / Beauty	Religion / Magic	Decoration	Health / Sanity	Research	Gold	Loyalty / Affection
Age of Empires Onl.					√		
Age of Mythology		√					
Cities: Skylines	√						
Civilization V	√	√			√		
Don't Starve				√			
Dragon Age: Inq.		√	√	√			
Empire: Total War	√						
Far Cry 4			√	√			
Majesty		√				√	√
Minecraft			√				
Rimworld	√						
Sim City 4	√						
Skyrim		√		√			
Stardew Valley						√	√
Stellaris	√						
Stonehearth			√			√	
Tropico 5	√		√				√
World of Warcraft		√					√

Figure 3: List of the respective games and the gameplay effects of their gardening mechanics

The so-called "Chantry Garden" in *Dragon Age: Inquisition* (BioWare Edmonton 2014), for instance, is presented as a rare space of repose in a world torn by warfare. It is explicitly modeled after a monastery courtyard and sees monks and soldier wander among flower beds and statues of ancient gods (see figure 4).

Figure 4: The Chantry Garden in *Dragon Age: Inquisition* (BioWare Edmonton 2014).

While the location is a largely decorative, optional element in the game – the player can choose whether to have it built in his or her fortress or not – it does supply a steady stream of restorative, magical plants to tend to the wounds of the protagonists. It is a protected, enclosed space reserved for the "morally good" to retreat, ponder and "experience a transformation" (Bloom and Hobby 2010, 38). It marries the otherworldly health of the Garden of Eden with monastic retreat and meditation – and translates it, mechanically, into a steady supply of items that restore health and magical abilities.

While *Dragon Age: Inquisition* is an action-oriented, third-person roleplaying game – wherein the player directly controls only one character at a time – even a strategy game like *Majesty: The Fantasy Kingdom* (Cyberlore Studios 2000), that has the player manage a whole magical kingdom and numerous soldiers from a God-like perspective, translates the idea of a "garden" into very similar mechanics. It features a "Royal Garden" structure that can be built within a palace and serves as a place for special hero units to meditate and gain magical enchantments, while also increasing their "devotion" to the player. No matter what genre of game, it seems the mechanics for what makes a proper digital garden are eerily similar.

The remaining two-thirds of the games in question (figure 2 and 3) take a slightly more secular, but highly convergent approach, translating the existence of garden structures to a host of similarly positive effects for the player: In worlds where no magic or interventionist deities can exist, they instead provide "happiness," "beauty," or "loyalty" – all currencies, of sorts, typical for games that see the player control a larger group of individuals, often from an omniscient, managerial perspective. In *Tropico 5* (Haemimont Games 2014), for instance, where the player takes on the role of the dictator of an island nation tasked with improving his income and avoiding revolution,[2] having garden structures increases both a region's attractiveness to tourists and inhabitants alike (increase in "beauty"-value), while also making a specific faction of the simulated population more friendly (in this case, the environmentalist faction increases its "loyalty"-value). Similar mechanics can be found in the *Civilization* games, where a player's expansion on the map is limited by a "happiness"-value that decreases with the number of cities that he or she has placed – and only with gardens can said "happiness"-value be kept high enough to enable further progression and ultimately avoid the collapse of one's eponymous civilization.

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2 For an extended discussion of the *Tropico* series of games and their cultural contexts/ambitions, see Penix-Tadsen (2016, esp. 229-234).

Figure 5: Soldiers march past public gardens in *Tropico 5* (Haemimont Games 2014).

What these gardening elements supply for the player are generally considered "buffs" or "passive abilities" – they increase and support existing mechanics but generally do not enable any fundamentally new actions for the player. Instead of, say, a novel type of weapon (such as a crossbow that allows for long-range combat) the garden provides a slight bonus to a set of values that often have no dramatic effect in short term play (i.e. by increasing the "health"-value from 250 to 255 or making a simulated group of people slightly more "happy"), but often become crucial for the long-term success of the player's various strategies. While having a "happiness" of "+2" in *Civilization V* might not win or lose a game within a couple of minutes, its influence on expanding the number and size of one's cities certainly has a cumulative effect in overall gameplay.

Gardening elements are thus the flipside, mechanically, to "farming." Where "farming" generally involves the player laboring with the core mechanic of the game world – survival and character growth – often right from the beginning of a play session, "gardening" generally only becomes crucial in mid- to late-game play,[3] enabling the player to ensure lasting feasibility of his or her plans. There is, then, a structuring logic to most of these games between "farming" and "gardening" – short-term growth and long-term success.

3 "Gardening" might thus be proposed as a term for similar, not explicitly garden-related, passive mechanics as well: While "farming" in the abstract refers to performing a monotonous task like battling hundreds of easy enemies, "gardening" – as an analytical term – could be applied to all mechanics that add beneficial passive effects to gameplay, especially in the form of health-, magic-, and happiness bonuses, especially when these seem to be at odds with the forces (war, destruction, expansion) that drive the game onwards.

Figure 6: *Minecraft* garden (Grain 2015) vs. *Minecraft* farm (Lynd 2017).

Gardens of Empire

Even a game as interactive and open-ended as *Minecraft* – essentially a digital *Lego* set with no predetermined path to follow – often sees its players rehearse this farming/gardening opposition (see figure 6): a gameplay dynamic that turns elements of farming (like the growing of wheat to make bread) into a necessity for survival in the world, while elements of gardening (planting daisies, for instance) become purely decorative. Mechanically, flowers in *Minecraft* can only be turned into colorful dyes that help 'spice up' whatever gear the player has equipped or digital structure he or she calls home. Here, the notions of regeneration, meditation, and joy associated mechanically with a garden in the games discussed earlier have to be wholly supplied by the player; they are not coded into the game. Still, while *Minecraft* is fundamentally open-ended, many players nonetheless follow a basic progression (as various so-called "Let's Play" online video-series attest): After a first round of securing sheer survival through building shelter (*Minecraft's* world is, in most game modes, a hostile one) and setting up and securing a farm, decorative gardening usually follows – thus increasing the need for protective structures like walls and fences and tempting the player to mine or venture outwards to secure additional resources.

Through the opposing gameplay modes of (necessary) farming and (decorative) gardening, *Minecraft* summons a settler mentality from very minimal gameplay mechanics alone – without any forced progression or story elements, most *Minecraft* scenarios still tell the same story of Lockeian conquest: the taming of the wild by the work of one's hands (thereby making it one's own), followed by a surplus of resources and labor that finds itself channeled into pleasure activities which, in turn, require increased protection and still more resources. Thus, even *Minecraft* tends to follows the same logic and gameplay loop – on a micro scale – that sees whole tribes of people in *Civilization* advance from a Neolithic state (farming as sustenance) into city states (gardening to give value to enclosed living) and expansionism (upkeep of beauty). This set of digital building blocks has successfully distilled down the work (farming) and reward (gardening) structure hardcoded into gaming: here, there is no need to give the player a "buff" to a "happiness"-value – he or she will just experience the sensation when entering their structure, built from nothing by the pixelated sweat of one's digital brow.

Even with its innocent presentation – its retro, pixelated, child-friendly graphics – the often highly creative gardens of *Minecraft* are as much monuments to settler culture (cf. Cavanagh and Lorenzo 2017) as *Civilization*'s simulated march through human history and "progress."[4] Like the other games discussed here, it tempts the player to situate leisure and relaxation into a context of expansion and conquest. Deforestation is a logical first step in a game that has monsters appear even in broad daylight, should the trees' canopy provide them with enough shade; protective walls are the next step - and any time thereafter, when the player wishes to experience pixelated Nature directly, he or she is faced with either risking one's digital skin in dangerous outside world or recreating the simulated Sublime in an enclosed garden structure. It is no wonder, then, that the *Minecraft* community seems to have spawned its own 'back to nature'-movement to combat these enclosure-trends.[5]

What such mechanics then underscore – even in their most stripped-down versions – is that the garden in videogaming is a *conceit*. It is a balancing act that acknowledges an apparent wrong in the game world – military occupation in *Empire: Total War* (Creative Assembly 2009), urban noise and pollution in *Sim City 4* (Maxis 2003), political repression in *Tropico 5* – but instead of asking the

4 *Civilization* notoriously ties vertical and horizontal growth of society to cultural advancements and retroactively naturalizes nation states: A player might start as a "German" tribe lead by a never-aging Bismarck and advance through time at a pace determined by the size of one's empire – the larger the cities, for instance, the higher their cultural output, allowing these "Germans" to achieve milestones like the alphabet or sailing faster than others. Nomadic peoples, on the other hand, are rendered by the game as uniform, cultureless "Barbarians" who function, mechanically, more like hostile wildlife than human tribes: they are uniform across the map, always hostile, and stand in the way of player expansion. On notions of progress, culture and history in *Civilization*, see Ford (2016) and Ghys (2012). For another take on the naturalization/biologization of the nation state in the franchise, see Poblocki (2002).

5 This trend has become so prevalent that *Minecraft*-players have even begun publishing self-made modifications of the game that allow for a "back-to-Nature"-style of gameplay. The Thoreau-inspired "Life in the Woods"-addition, for instance, brings with it numerous mechanical and graphical changes that aim to allow for a life in *Minecraft* that is more in tune with "Nature." As odd as it might seem, this digital space has birthed its own naturalist movement, its own peculiar brand of 8-bit Transcendentalism. "For me personally," writes the creator of "Life in the Woods," "it was also all about solitude, loneliness, and having to fend for yourself, with no one else to depend on" (Phedran 2016).

player to address it at its core, supplies a means to offset the resulting negative effects. For instance, taking over a small city in *Civilization V* with a population value of "1" by military force would subtract 1.33 "happiness" from the player's account – risking a drop below zero, should his or her "supply" of happiness be "1" or less, which would reduce the empire's overall income and productivity. With the right religious belief chosen by the player, a single garden structure could offset this penalty for military aggression.

The garden in videogames truly follows a *panem et circenses* strategy when it comes to simulating or gamifying real-world dynamics. By reducing the complexity of gardening mythos and practice to a numerical increase in a generic, all-encompassing value like "happiness" or "health," the virtual gardens turn it into a currency that can be spend on necessary items for internal growth and external expansion. Like a morality system in certain role-playing games – where, for instance, a murder can often be offset by a handful of "good deeds" – merely hoarding this currency makes little sense past a predetermined threshold.[6] A player might, then, look at his or her "happiness" account and, finding a solid surplus there, consider expanding some more to not let it go to waste. Thus, the digital garden's healthfulness is always intricately connected to squalor, pollution, and disease, and its serene religiosity to warfare, violence, and struggle. To do good, by building a garden, only makes sense to offset a "bad" – and any "good" and "bad" are on the same scale and can counteract each other.

Victory Gardens

While such mechanics appear quite reductive, it would be shortsighted to either decry these games' lack of "realism" or be overly hasty in condemning their somewhat relativist take on human morality and societal self-regulation. Indeed, in operationalizing the garden in such a way, these games allow users to consider its complicities in real life. That greenspaces like public gardens – and in a more individualized way, private gardens – are used in city planning to offset traffic and urban crowding is certainly not a novel insight. But doesn't this decision also involve a similar them/us logic as *Sim City*'s gardens? The greenhouse effect certainly cannot be made null by a nice garden – but a nice garden might make a specific group (citizens of a country, city, town) see less urgency in regulating high-density car traffic than a population not experiencing the positive mood-effects of the said garden(s), while certainly experiencing warming and loss of air quality.

Furthermore, one need not look far into the past to find gardening employed in North America and Europa in a manner that bears striking resemblance to the mechanics used by the more warlike games discussed here.

6 While, for instance, there are some accumulative positive effects per "amount" of (positive) happiness in *Civilization V*, "spending" much of the surplus "happiness" on war and expansion is generally the more advisable strategy. Thus, many guides to the game explicitly talk about "Managing Unhappiness" when talking about this currency (see, for example, Ratcliff 2014).

During the World Wars, for instance, Great Britain's Victory Gardens, the United States' School Garden Army, and Canada's War Gardens hoped to build a "stronger and healthier nation" through a push for the citizenry to garden, often on public, urban land (cited in Moon 2016, 163). The stated goal was to improve the moral and spiritual wellbeing of the individual, family, and nation. The beautification of the home and community by gardening provides healthful physical exercise, recreation, and definite release from war stress and strain (see also Gowdy-Wygant 2013).

Besides alleviating food shortages, Victory Gardens became a prime morale booster that enabled a continuation of the conflict – and did so by explicitly connecting the war effort to notions of self-making and pride, health and meditation, as well as religiosity, so enmeshed with the very concept of the garden in Western thought for centuries (cf. Francis and Hester 1995). The same strategy was employed on the other side of the trenches: not only during the wars, but also following WW2, when the German equivalents of these gardens became one of the driving motivational forces of postwar recovery (cf. Karge 2016, 24-25). Looking further into the past, one might discover that even "monastic identity," in the middle ages, "was negotiated through direct, constant confrontations with war and warriors" (Smith 2013, 197) and thus the peaceful, meditative garden of the monastery might just have to be reconsidered as part of broader bellicose developments and strategies of the age.

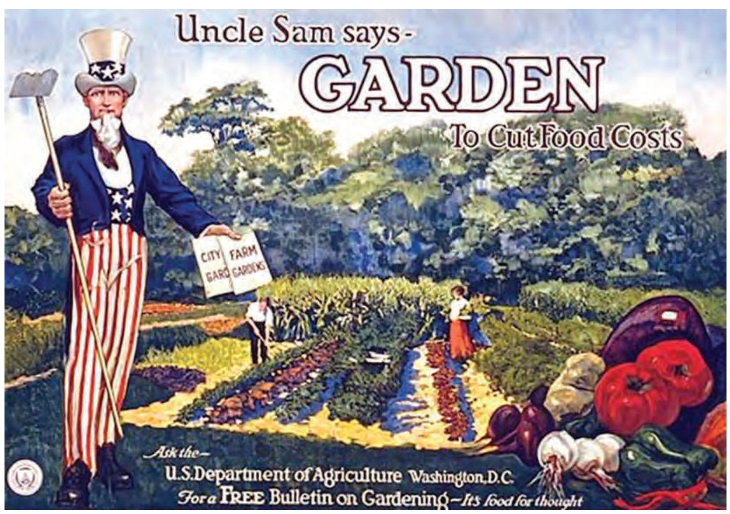

Figure 7: US Victory Garden Propaganda ("Uncle Sam says" 1917).

Given the complex history that strategic games and military planning have shared since the 1800s (cf. Dor 2016), the mechanics discussed here, seem, at times, to almost force a critical reevaluation of the garden in Western history on the player's end. Gardens in the games discussed do not just 'happen' accidentally, nor are they always already present in the game world: they are consciously placed there as part of a strategic decision. The rich mythology of the garden, thus, has to be *used* in terms of means and ends – the player has to consider whether the (monetary or resource) expense and potential building time associated with the structure are worth the positive effects to be gained from it.

There is a specific point in time when the garden becomes a wise investment, either dictated by gameplay-mechanics or by a game's more 'natural' progression systems: In the city builder *Cities: Skylines* (Colossal Order 2015) it is when one's town is about to be considered a "boom town," in *Civilization V* it happens generally during the Medieval era, and in *Minecraft*, it tends to follow basic base und perimeter construction. In these moments, the politics of the garden come to bear directly on gameplay decisions – and even when the overarching systems of the game tend to favor certain strategies (in *Civilization* it is war, in *Cities: Skylines*, massive growth, etc.) the decision to adhere or resist is up to the player. Still, even following these morally dubious strategies means encountering the garden as a problematic *institution* – a societal response to specific cultural and environmental problems – and not as a naturalized element of culture that is "just there" and has always been. It trains the user of the game to encounter the garden as a response to a question that is generally counter to the aura of peace, health, and religiosity that still surrounds the space to date. It politicizes and contextualizes a place that tends to elide any notion of politics to instead deal in metaphysics and non-temporality. This opposition between what the garden *does* and what the garden *says it is* becomes thematized by the conflict between gameplay mechanics which emphasize problem-solving or balancing (for instance: gardens to mollify war weariness) and graphics and in-game texts that deal in a garden mythos that obscures these very functions (cf. figure 4).

It is perhaps no coincidence, then, that one of the most explicitly meta-textual elements of *Dragon Age: Inquisition* can be found in the rendition of its peaceful monastery garden, at the dead center of which stands a pavilion featuring a chess-like game set-up. Here, the conflict between garden aura and mechanics are analogized in two generals sitting in the soothing shelter of a luscious garden, filled with religious iconography, playing a war strategy game to sharpen their minds for the conflict ahead. The peace of the garden, this scene reminds the player, requires the war outside its walls to sustain itself.

While such moments of meta-commentary on gardening mechanics are still rare, especially in mainstream videogaming, there is one example that is very upfront about it. The independently produced art game *A Good Gardener* (Lodwick and Endsley 2014) takes the central conflict of the garden in videogaming – between what it *does* and what it *pretends to be* – and collapses it in on itself. The game quite literally opens on a War Garden: The player finds him-/herself in the shoes of a prisoner of war, tending to a small plot in the ruins of a former (civilian) home. Overnight and seemingly in secrecy, fully grown plants are harvested and the monotony of gardening is only occasionally interrupted by an overseer stopping in and musing about life and death. The purposefully simplistic mechanics of the game consist of the most innocent components of gardening: watering and planting seeds. There is nothing to balance, no strategical thought to be had: faced with the prospect of execution for insubordination, the player lives through what a simple worker in a besieged city in *Civilization* might experience.

Gazing past the broken walls and windows of one's enclosure, the player can spot ruined factories and, after a few in-game days of play, will notice more and more smoke billowing up in the distance, followed shortly by encroaching flames. The strict separation, promised by the garden, between inner sanctum and outer conflict – between self-making and being unmade – is threatening to give way once and for all. Still, all the player can do is plant and water while the world around is consumed by fire. The drama of the outer world and the increasingly nonsensical task of gardening – and consequently, the preposterous idea of balancing out war with pretty flowers – turn the central mechanic of the short game into a mystery: What is the point to all this gardening?

Figure 8: "A Good Gardener" (Lodwick and Endsley 2014)? From left to right: bomb plant, sword plants, spear plants, sword plants.

The revelation will come shortly before an unspecified foreign army is to invade the structure, only to be persuaded by the overseer to just let it burn to the ground with the player inside. Faced with the coming end of his spiritual sanctum, the overseer chooses the death of his gardener over having his hallowed space violated by politics and war. Still, this place is all about the latter; only minutes earlier, the player had learned the actual purpose of the place: the garden skipped all pretense at merely 'raising morale' – and produced weapons instead. The oddly shaped, colorful flowers the player had been growing all along turn out to be staples of videogame warfare: shuriken, grown from bushes, lengthy bamboo-like flowers that are really spears, bulging blue bomb-fruits, and even curved ferns, which can now be read as arabesque swords (cf. figure 8). A player familiar with videogame history will immediately recognize iconic weapons from classic videogame franchises like *Prince of Persia*, *Zelda* or

Ninja Gaiden here. In the bellicose worlds of videogaming, there can be no "Good Gardener" – unless violence is explicitly made impossible in the game world, every garden is a victory garden, every flower enclosure a tool of ideological manipulation, and every potted plant a small icon of looming war.

The garden as a videogame mechanic is thus a double-edged sword – but it is a *sword* nonetheless. While its direct impact on the gaming world seems antithetical to violent conflict, it is this very notion that makes it a necessary tool for running a powerful, expansive empire, creating a bustling metropolis, winning a magical war, or being a successful settler conquering the wild. The garden is a tool for domination, these games insist – and every digital gardener is a soldier in disguise. This certainly seems quite the proposition to make to any real-world gardener – whether they pursue their hobby in an actual former Victory Garden or in their own front yard. Still, while these games offer a distilled, somewhat simplistic take on the purpose of the garden in Western society, their lessons might still be worth pondering. Be it as a consumer in late capitalism, as a citizen in a liberal market-democracy or a more autocratic system, or as an owner of a disproportionate carbon footprint – the question of what *exactly* is meant to be offset by gardening, psychologically and institutionally, can point us to a host of issues that the garden might be a *response* but perhaps not the best *solution* to. In the end, even the garden cannot escape a complex world of contingencies – and every Ithuriel's Spear, Sword-Lily, or Cannonball Tree ornamenting one's own green sanctum serves as a reminder of that.

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Figure 4: BioWare Edmonton. 2014. *Dragon Age: Inquisition*. Redwood City, CA: Electronic Arts.

Figure 5: Haemimont Games. 2014. *Tropico 5*. 2014. Worms, GER: Kalypso Media.

Figure 6: Grain. 2015. "How To Improve Your Minecraft Garden!" *YouTube*, November 21. Accessed November 13, 2017. https://www.youtube.com/watch? v=b11mIeju0E0

Figure 6: Lynd, Alicia. 2017. "Minecraft Barn Farm and Windmill and Fence." *Pinterest*, March 26. Accessed November 13, 2017. https://www.pinterest.com/pin/ 138837600990372316.

Figure 7: "Uncle Sam says." 1917. Library of Congress Prints and Photographs Division, Washington, D.C.

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Volcanoes in video games: the portrayal of volcanoes in commercial off-the-shelf (COTS) video games and their learning potential

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Abstract. Volcanoes are a very common staple in mainstream video games. Particularly within the action–adventure genres, entire missions (e.g. *Monster Hunter: Generation Ultimate*, 2018) or even full storylines (e.g. *Spyro: The Reignited Trilogy*, 2018) can require players to traverse an active volcano. With modern advancements in video game capabilities and graphics, many of these volcanic regions contain a lot of detail. Most video games nowadays have gameplay times in excess of 50 h. *The Legend of Zelda: Breath of the Wild* (2017), for example, brags a minimum of 60 h to complete. Therefore, players can spend a substantial amount of time immersed within the detailed graphics and unknowingly learn about volcanic traits while playing. If these details are factually accurate to what is observed in real-world volcanic systems, then video games can prove to be a powerful learning tool. However, inaccurate representations could instil a false understanding in thousands of players worldwide. Therefore, it is important to assess the accuracies of volcanology portrayed in mainstream video games and consider whether they can have an educational impact on the general public playing such games or whether these volcanic details are overlooked by players as they focus solely on the entertainment factor provided. We have therefore reviewed several popular commercial video games that contain volcanic aspects and evaluated how realistic said aspects are when compared to real-world examples. It was found that all the games reviewed had a combination of accurate and inaccurate volcanic features and each would vary from game to game. The visual aesthetics of these features are usually very realistic, including lava, ash fall and lahars. However, the inaccuracies or lack of representation of hazards that come with such features, such as ash-related breathing problems or severe burns from contact with molten lava, could have great negative impacts on a player's understanding of these deadly events. With further investigations assessing the direct impact on the general public, there is an opportunity to correctly assess how to incorporate the use of mainstream video games in educational systems and outreach.

1 Introduction

1.1 Commercial off-the-shelf vs. educational video games

Video games can be categorised into different groups, based on playable design, graphic style or genre. The focus of this investigation will be on mainstream or commercial off-the-shelf (COTS) video games as opposed to educational games. Educational games have been intentionally designed to teach the player about particular topics. They are often developed with input from teachers to ensure the information included is factually correct, and they sufficiently cover the topic of interest. While the use of educational games has been heavily researched (e.g. Oblinger, 2004; Kerawalla and Crook, 2005;

Squire, 2005; Van Eck, 2006; Squire et al., 2008; Charsky, 2010; Wiklund and Mozelius, 2013; Lelund, 2014; Chen et al., 2015; Rath, 2015; Mozelius et al., 2017), most conclude that players, particularly children, tend to lose focus or enthusiasm for such games, nullifying the educational benefits they could provide (Kerawalla and Crook, 2005; Van Eck, 2006; Charsky, 2010; Floyd and Portnow, 2012a, 2012b; Lelund, 2014). However, if games are designed and implemented appropriately, the opposite effect can happen and improve a user's learning (Mani et al., 2016). COTS games, on the other hand, are designed primarily for entertainment and therefore retain the focus of players for much longer (Squire, 2005; Van Eck, 2006; Squire et al., 2008; Floyd and Portnow, 2012a; Turkay and Adinolf, 2012; Wiklund and Mozelius, 2013; Lelund, 2014; Mozelius et al., 2017), with most modern COTS games offering numerous hours of gameplay that can exceed 50 h (e.g. *Legend of Zelda: Breath of the Wild; Witcher 3: Wild Hunt; The Elder Scrolls V: Skyrim*). COTS games also have an advantage over educational games in their appeal that enables them to reach millions more players around the world (Mayo, 2009; Floyd and Portnow, 2012b). While the benefits of learning through commercial video games may not be as obvious or as structured as standard learning through an educational system, when exposed to situations, such as unplanned tests, students can surprise themselves with what they have learnt from games such as improved knowledge of historical events after playing the *Assassin's Creed* series (Kline, 2020).

1.2 Using educational games to teach STEM subjects

The use of educational video games is becoming an increasingly popular concept as a teaching method (Gros, 2007; Squire, 2008; Lelund, 2014). A key benefit of educational games is that they are specifically designed with a tailored content that can be directly implemented within an educational setting. A level system that gets progressively more difficult as the student progresses within the game can also allow students to ease into a new situation as they build up their understanding of scientific concepts (Gros, 2015). Utilising a video game's ability to change different controlling factors to generate differing outcomes makes them a powerful tool for STEM subjects. Not only do the students gain hands-on experience but they can also gain immediate results, allowing them to explore how varying factors influence the outcome of experiments.

Shute et al. (2013) created an educational game called *Newton's Playground*. The game required students to draw routes that allowed a green ball to reach a red balloon. Each of the methods that allowed the ball to advance further directly obeyed basic rules of physics, including gravity and Newton's three laws of motion. Statistical analysis not only revealed that playing *Newton's Playground* led to an improved understanding of the physics concepts instilled in the game but also that the students who engaged more with the game, reaching the higher levels, showed the largest increase in post-test scores.

In another example, Pringle et al. (2017) created a forensic science educational video game that allowed university students to conduct a full burial excavation, including doing background research, field reconnaissance and eventual excavation of potential sites. Feedback from the students stated that they found the game to be very useful, engaging and generally accepted to be an enjoyable experience. However, some students were concerned about using the game as a formal assessment, because peers who would struggle with the technology could suffer poor marks.

One of the major problems with using educational games lies within their development. In order to create a video game that has enough factual content to be properly implemented into a course and is engaging enough for the students, a considerable amount of time must be invested for the creating, trailing and improving of each game (Pringle et al., 2017). In addition to this, many educational games of this style are developed through funded research projects (Mani et al., 2016; Pringle et al., 2017). As a result, a considerable amount of funding would be required to mass produce educational games for widespread distribution to schools and/or universities.

1.3 Using COTS games to teach STEM subjects

The major downside to COTS games is that because their focus is more on entertainment than education, they can contain numerous unrealistic or inaccurate features, which could instil a false understanding of real-world dynamics within players. Such inaccuracies may be introduced into a game for a variety of reasons: cost and development times are too high, lack of research conducted by the developers, or that it provides a higher entertainment value or risk factor than realistic expectations. However, with careful guidance, this issue could easily be overcome (Floyd and Portnow, 2012b).

Science and scientists themselves are not the most common staples in COTS games, usually showcased as singular characters that assign some objectives required to progress (e.g. the academy scholars in the *Monster Hunter* franchise), or the games are developed as niche simulators (e.g. *Surgeon Simulator*). However, there has been some research in the representation of science, scientists and other types of people in COTS games, e.g. the portrayal of technoscience (Dudo et al., 2014), biotechnology (Murdoch et al., 2011) and the representation of queer people of colour (Smith and Decker, 2016). However, this is not to say that realistic science does not exist within standard commercial games of other genres (e.g. adventure, shooter or racing games). Technological advancements in commercially designed games have allowed developers to simulate real-world principles (Mohanty and Cantu, 2011). This makes games such as *Zoo Tycoon, Roller Coaster Tycoon, The SIMS* and even *Angry Birds* excellent candidates for improved learning of STEM-related subjects, including mathematics, physics, chemistry and economics (Mayo, 2009; Sun et al., 2015; Klopfer and Thompson, 2019).

Mohanty and Cantu (2011) used commercial PlayStation-3 games to teach physics to undergraduate students. Taking examples from games like *Shaun White Skateboarding*, students were asked to measure the speed of the character, and in *Little Big Planet*, students calculated the motion of projectiles launched from cannons they could build within the game. At the end of the study, comments from the participating students positively supported the notion of using video games as a teaching method. Many liked the ability to gain direct, first-hand experience of scientific concepts, and the study even led to tangential learning in one student, who noted how inaccurate the physics mechanics of the main character in *God of War* were by breaking the first law of Newtonian mechanics.

Research by Gampell and Gaillard (2016) used a mixture of disaster education-oriented video games (*Stop Disasters*, *Disaster Watch*, *Inside Haiti* and *Earthquake Response*) and two COTS games which have disaster elements (*Fallout* and *SimCity*) to see how they instil disaster awareness and portray hazards, vulnerabilities, capacities, disasters and disaster risk reduction, as well as game content, player motivation, skill building and social interactions within these games. Similar to the argument of this paper, findings suggest that video games have the potential to be positive learning tools to reinforce disaster risk reduction messages. A more recent study used constructivist learning theory to explore the ability of "serious" disaster video games to create student participation in learning within schools, and findings state that teaching and learning processes for both teachers and students need to be considered more in terms of the pedagogic process for the ability of students to enable deeper discussions and engagement with the curriculum (Gampell et al., 2020).

The Science Hunters project (Hobbs et al., 2019) utilised the popular COTS game *Minecraft* to engage children in scientific subjects, including plant biology, animal adaptation, volcanology, flood management and much more. In the case of animal adaptations, children were tasked with creating an animal that had adapted to particular habitats, using the building blocks *Minecraft* provided. They would then have to explain their choices, such as using orange coloured blocks to camouflage the creature in an orange-sand desert.

COTS games cannot be used to completely replace standard teaching methods as they will not be structured or in-depth enough to cover a full syllabus. However, if correctly implemented to facilitate sessions as they have been done in the examples above, then the positives can be of great benefit to both students and staff involved (Van Eck, 2006; Floyd and Portnow, 2012b).

1.4 Geoscience within video games

Despite the numerous investigations mentioned above, there have been very few specifically targeting geoscience-related learning via video games. Chen et al. (2015) tested a self-designed role-playing game (RPG), which was heavily focused on geoscience-themed research, to help students with their curricular learning. From the results, they found there to be no significant statistical difference in the scores between groups of students who played an RPG game compared to those who did not. However, as this was an educational game as opposed to a COTS game, the lack of knowledge gained by the students may be due to the style of the game not being entertaining and engaging enough (Chen et al., 2015).

Another geoscience-related educational video game created was *St. Vincent's Volcano*, created by Mani et al. (2016). Developed as an educational game, *St. Vincent's Volcano* was intended to be used to enhance volcanic hazard education and communication to local communities around the real-world volcano La Soufrière, located in the Lesser Antilles. Candidates (both students and adults) took a quiz prior to playing *St. Vincent's Volcano* to establish a current understanding of local volcanic hazards. Afterwards they took part in a 6-week trial period playing the game before retaking the quiz. The results showed an increase of over 10 % in the post-test results compared to pre-test results, as well as a genuine increase in the candidate's interest in volcanic hazards, both amongst the students and adults.

More recently, Hut et al. (2019) compared whether geoscientists or non-geoscientists had a greater ability to determine whether a landscape was real in a video game. The prompt behind the study was related to vast improvements in video game graphics, allowing for more wondrous natural environments (*Legend of Zelda: Breath of the Wild, Middle Earth: Shadow of Mordor, Red Dead Redemption*), and the amount of time players spend immersed in said games could pose as an opportunity for tangential learning (Hut et al., 2019). While geoscientists were able to correctly identify more images as being virtual or real than non-geoscientists, the results suggest that non-geoscientists are still capable of determining the difference to an extent that the potential of erroneous learning (the learning of wrong or false information in the belief that it is correct) is low. Therefore, this suggests that there should be no risk in tangential learning of geological concepts even if incorrectly presented in a video game.

As briefly mentioned above, one of the major negative sides to using COTS games as a form of tangential learning is that they can often contain inaccurate features that would misinform players and lead to erroneous learning (Rath, 2015; Mozelius et al., 2017; Hut et al., 2019). This could be due to a number of reasons, from the developers not fact-checking their sources to the game being more entertaining when aspects are exaggerated. Previous research by Parham et al. (2010, 2011) has already highlighted several volcano-topic areas where Hollywood films such as *The Core* have led to false understanding of our planet and volcanic eruptions in students. This includes the belief that atmospheric changes can trigger volcanic eruptions and that said volcanoes are only found in tropical environments (Parham et al., 2010). Therefore, it can be assumed that popular video games could also have a similar impact on a student's understanding of volcanic systems found within COTS games.

This paper is part one out of two, focusing on an overview of COTS video game educational potential. The second part of the investigation will be to explore what people do learn whilst playing COTS games. The aim of this investigation is to identify areas of volcanic features that are common within COTS video games and apply real-world context to said features in order to determine how realistically they are presented. This will help to (1) highlight areas within volcano-related teaching where players may pick up erroneous learning and (2) promote various COTS games to increase their enthusiasm towards the subject and encourage further tangential learning (Floyd and Portnow, 2012b). The latter would not only have benefits within an academic teaching environment but also for outreach events.

1.5 Potential for self-learning

Outside of the education system, video games have an amazing potential to stimulate self-learning. There are two particular types of learning that can be induced from playing COTS games. Tangential learning is the process of self-educating oneself through exposure to a topic in a context that they already enjoy (Floyd and Portnow, 2012a, b). This can include a range of outputs from watching films and documentaries to playing sports or games. With video games being so popular with millions of people around the world, the use of tangential learning by playing such games could prove to be a powerful tool for encouraging student interaction or boosting public engagement. *God of War*, for example, has the potential to interest players in Greek mythology as the players interact with various Greek deities and other mythological beings (Turkay and Adinolf, 2012).

Incidental learning refers to learning that is unplanned and often unconscious in nature, which develops through engaging in tasks or activities. In regard to video games, players can become so focused on completing missions or drawn into the storylines that they do not register what they are learning at the same time. *Assassin's Creed 2* is set in Italy during the Renaissance, with several maps that allow the player to fully explore the cities and learn about culture, politics and historical events of the time while progressing through the game's storyline (Turkay and Adinolf, 2012).

It is this potential for self-learning outside of educational environments, where the games are not forced upon the players, that has seen the least amount of analytical attention and therefore is the basis of exploration in this study. How much, as players, do we truly learn while casually playing a commercial video game for entertainment? And, because the information in these games is not fact-checked, how much of this information is scientifically accurate? For the purpose of this research, the investigation shall focus on volcanic systems and features found within video games.

The hypothesis is that there will be a range of volcanic features represented. With volcanic regions being so prominent in COTS video games and volcanoes presenting a multitude of hazards in the real world, developers have access to a diverse pool to create unique environments and levels that will set them apart from other volcanic regions in other games. However, it is not expected that all of these volcanic features would be realistic, as COTS video games are designed with entertainment in mind. They allow players to venture into virtual fantasy realms beyond the limits of our own world. Therefore, many volcanic features found within the video games could be shaped into captivating landscapes or manipulated to provide a challenging yet achievable task.

2 Method

To determine which volcanic features commonly occur in COTS video games, a variety (11 in full and several partial reviews to date) of video games from popular franchises and titles were selected, including *The Legend of Zelda, Pokémon, Spyro, Tomb Raider* and *Minecraft*. These games span an assortment of consoles, played on the Nintendo Switch, Xbox One and PC. Each game was chosen because it contains known extensive volcanic regions or levels that could be interacted with to make observations on the geological features found. Additionally, as with most COTS games, the games have all been developed with player entertainment in mind, as opposed to primarily educating them.

Numerous hours were spent exploring the maps and levels that contain volcanoes and looking at features including texture, graphics, and flow mechanics of lava (both molten and solidified); shape and eruption style of the volcano; hazard assessment and impact on local populations; and more. With each example, comparisons were made against the visual representation in the video game to real-world examples. In cases where the game shows inaccurate representations, corrections were provided.

Selecting video games

Beyond the main requirement of the video games being popular COTS games, we made sure to include a broad range of game styles. Whilst most of the games we have chosen are part of the role-playing game (RPG) and action–adventure genres, there is a fair representation of the current commercial video game market. However, video games also come in multiple forms: single-player, multiplayer, online, open world, linear story, etc. Each variant changes the gaming experience and as such would alter the way the player would learn. For example, in multiplayer games, a number of players will work together towards a common goal. Single-player gameplay, on the other hand, will see an individual solve a problem on their own. It is therefore essential to cover such a range in order to understand how COTS games can be best utilised for educational purposes.

3 Volcanic features within COTS games

3.1 Volcano shapes and styles

In the real world, volcanoes can come in a range of shapes and styles (shield, stratovolcano, caldera, fissure, etc). What is found in video games is a preference towards stratovolcano or caldera styles (Table 1), and a definite lack of volcanic styles such as shield or fissure. In most cases, in-game stratovolcanoes are very large and steep sided and tower over the landscape compared to real-life counterparts (Fig. 1). When the games require a volcano to cover a large area, they tend to opt for calderas (*The Legend of Zelda: Breath of the Wild*, 2017 and *Subnautica*, 2018). As calderas are usually extensive, from 1×1 km to 40×75 km (Cole et al., 2004), this is an understandable choice for developers. Whilst shorter volcanoes may not look as dramatic as taller ones, they naturally produce larger-scale lava flows or fields (e.g. Kīlaeau, Hawai'i, or Laki, Iceland) that are better attuned to the common video game representations of lava.

3.2 Lava flows

Lava flows are found to be the most represented volcanic feature within video games, appearing in nearly everyone reviewed (Table 1). Each depiction of lava flows was reasonably aesthetically accurate, including evidence of high viscosity and cooling surfaces (Fig. 2a). Even in the cases of solidified lava, pillow lavas (Fig. 2c), ropey pahoehoe (pāhoehoe) (Fig. 2b and d) and columnar textures (Fig. 2e) could be found, adding to the different forms that players can learn about. The accuracy of the detail in each video game feature can be seen when compared to real-world examples of the same features (Fig. 2f–h).

Rivers of flowing lava or lava lakes, on the other hand, tend to be more exaggerated, either in their sheer size or length. *The Legend of Zelda: Breath of the Wild* (2017), for example, boasts a two-tiered caldera, called Death Caldera (Death Mountain). That volcano has two caldera rims, both overflowing with lava flows to such a scale that it is unfeasible in the real world (Fig. 3). Or in the case of *Subnautica* (2018), the lava was found to be flowing underwater at temperatures and colours found on the surface (Fig. 4), instead of quenching and forming pillow lavas, which is what it does in the real world (Fig. 2f).

3.3 Tephra

The most common representation of tephra in COTS video games is in the form of volcanic ash. While less synonymous with volcanoes than lava flows, volcanic ash is still a very common product of real-world volcanic eruptions (e.g. Eyjafjallajökull, Iceland, 2010, and Taal, Philippines, 2020). From a developer's point of view, volcanic ash is an easy volcanic aspect to edit into a game via a particle effect, as seen in *Pokémon Emerald* (2005), *The Legend of Zelda: Breath of the Wild* (2017) and *LEGO Marvel Superheroes 2* (2017; Fig. 5 and Video Supplement 1). In the real world, volcanic ash can have detrimental effects on both social impacts (halting air traffic, collapsing roofs or destroying crops; USGS, 2019) and direct human health (respiratory problems and skin and eye irritation; Horwell and Baxter, 2006). Despite the common occurrence of volcanic ash in the games, these issues were rarely seen within the video games that were explored for this investigation. The best example found was within *Pokémon Emerald* (2005), where the volcanic ash produced by the volcano Mt. Chimney was causing local residents to wheeze and cough due to breathing in volcanic ash for a prolonged amount of time (Fig. 6).

Lava bombs are another recurring volcanic feature, usually added as an additional hazard that players must avoid while traversing the stage (e.g. *The Legend of Zelda: Twilight Princess* (2006), *Spyro: Ignited Trilogy* (2018), *Crash Bandicoot* (2018)). In the real world, lava bombs are a serious threat to those within range. Some video games do take this risk seriously and directly apply the same level of severity (Table 2). If a player's avatar is hit by a lava bomb, they can instantly die, usually respawning them at the previous save point (Video Supplement 2, *Sea of Thieves*, 2018). However, in some games particularly aimed at a younger audience, the realism is reduced to make the level difficulty more appropriate for players. They do this by having the avatar only take some health damage and sometimes stumble backwards but ultimately get back up again and continue on the path, dodging any further flying projectiles (*The Legend of Zelda: Breath of the Wild*, 2017).

Pyroclastic density currents (PDCs) are the least represented of the tephra volcanic hazards within COTS video games. In the real world, PDCs are one of the most, if not the most, dangerous hazards a volcano can produce. They are also a phenomenal spectacle to watch as a cloud of molten rock and superheated gases avalanche down the slopes of a volcano. Despite the potential excitement and risk a PDC could provide in a video game, they are sorely lacking. The only hint of a PDC evident was in the artistic design of the cliffs surrounding some of the volcanic zones in *Monster Hunter: Generations Ultimate* (2018; Fig. 7a). However, this is only an assumption made based on visual observations when compared to a real-world example (Fig. 7b). A virtual PDC has yet to be seen in motion.

Figure 1. Stratovolcanoes in *Monster Hunter: Generations Ultimate* © Capcom (2018; **a**), *The Shadow of the Tomb Raider* © Eidos-Montréal (2018; **b**) and *LEGO Marvel Superheroes 2* © TT Games Ltd (2017; **c**); aerial view of the stratovolcanoes Volcán de Colima (foreground) and Nevado de Colima (background) in Colima, Mexico (Edward McGowan, 2018; **d**); view of active Las Cańadas summit from within Caldera de las Cańadas, Tenerife (Edward McGowan, 2016; **e**).

3.4 Lahars

Lahars are slurry mixtures of volcanic material, debris and water (or ice), which are highly erosive and damaging, can flow over gentle gradients, and inundate areas far away from their sources, making them a distal volcanic hazard people sometimes do not anticipate (Wallace and Iverson, 2015). Whilst a common volcanic hazard for volcanoes that are ice or glacier capped (e.g. Nevado del Ruiz, Columbia and Mt. Rainier, USA), have a crater lake present (e.g. Taal Volcano, the Philippines, and Mt Ruapehu, New Zealand), or are locations that experience heavy rainfall (e.g. Volcán de Colima, Mexico and La Soufrière, St. Vincent and the Grenadines), lahars only feature in *The Shadow of the Tomb Raider* (2018; Fig. 8 and Video Supplement 3), being a sequence that must be traversed in order to progress in the game. The mechanics of the large flow itself were realistic, with the understanding of the dynamics between the ratio of sediment and water content and its bulldozing power by destroying property and infrastructure. However, the sudden opening of large cracks and gaps subtracts from the realism of how lahars interact with the environment.

3.5 Volcanic gas emissions

Volcanic gases are by far the least represented aspect of volcanology, with barely a mention of them within the video games tested. However, in *The Shadow of the Tomb Raider* (2018), there is a sequence where the volcanic hazard is volcanic haze, tephra or a mixture of the two (Fig. 9), which results in the character covering their mouth, coughing, receiving slow damage and eventually leading to death if lingering for too long. However, the confusion and perhaps misinterpretation of not being entirely clear if it is volcanic haze or tephra could diminish tangential and/or incidental learning. This is disappointing, because there is a very large portion of volcanological research being conducted on gas emissions to further our understanding of predicting eruptions, volcanic effects on climate and more. Without the inclusion of volcanic gases in COTS video games, many players may never understand their importance.

Table 1. A summary of volcanic features in individual COTS video games. Features are colour-coded based on if they are realistic (green), unrealistic (orange), or both realistic and unrealistic (blue) and if there was insufficient data to determine accuracy (yellow) or not applicable due to no examples (N/A; white).

Video Game	Volcanic Feature							
	Volcano Shape	**Molten Lava**	**Lithified Lava**	**Ash Plume**	**Ash Fall**	**Volcanic Gases**	**Lahar**	**Pyroclastic Density Current**
Assassin's Creed: Odyssey (2018)	Realistic composite/ stratovolcanoes	Realistic lava colours and textures with cooling surface	Realistic pahoehoe and ropey lava textures, matching the molten lava type	Convection of a plume and some atmospheric boundary spreading. However, no plume drift associated with wind interaction	No clear ash fall visual effects	N/A	N/A	N/A
Crash Banicoot N. Sane Trilogy (2018)	N/A	Realistic lava colours and textures with cooling surface	N/A	N/A	N/A	Possibly, there are small geothermal vents that make appearances	N/A	N/A
Hot Lava (2019)	No signs of a fissure vent to supply the lava	Realistic lava colours and textures with cooling surfaces	Realistic pahoehoe and ropey lava textures, matching the molten lava type	N/A	N/A	N/A	N/A	N/A
LEGO DC Supervillians (2018)	Cannot see crater to determine fully	Realistic lava colours and textures with cooling surface	Realistic pahoehoe and ropey lava textures, matching the molten lava type	N/A	N/A	N/A	N/A	N/A
LEGO Marvel Super Heroes 2 (2017)	Realistic composite/ stratovolcano	Realistic lava colours and textures with cooling surfaces in places	N/A	The top of the plume being directed away from vent due to prevailing winds	Constant falling of ash particles in the vicinity of the volcano	N/A	N/A	N/A
Minecraft (2009)	Unrealistic lava pools randomly located around. No raised crater rim	Generic flowing lava colours and degassing bubbles. Decreases in volume as it flows further from source	Selection of several volcanic rocks including andesite and dacite, with realistic colours	N/A	N/A	N/A	N/A	N/A
Monster Hunter: Generations Ultimate (2018)	Unrealistically large strato-volcano. Mostly hollowed out on the inside	Unrealistically long, meandering lava river that does not match the expectations of the large volcano nearby	A range of lava textures that vary based on their location on the map. Although they have been smoothed over and lose detail	The top of several plumes show ash being directed away from vent due to prevailing winds	No ash fall is seen in any location, despite numerous nearby ash-laden plumes	N/A	N/A	Cliff faces closely resemble a dissected pyroclastic deposit
Pokémon Emerald (2005)	Realistic composite/ stratovolcano	Appears as generic lava colours and degassing bubbles	Appears as generic rock colours/texture	No ash plume seen above the active volcano, despite ash constantly falling	Constant falling of off-white coloured ash particles north of the volcano, suggesting a prevailing wind	Bubbling lava indicates expulsion of gases/ degassing	N/A	N/A
Pokémon Silver (1999)	Realistic composite/strato-island volcano	Appears as generic lava colours and degassing bubbles	Appears as generic rock colours/texture	N/A	N/A	Bubbling lava indicates expulsion of gases/ degassing	N/A	N/A
Sea of Thieves (2018)	Realistic composite/strato-island volcano	N/A	N/A	N/A	N/A	Gases escape fissures when the volcano erupts	N/A	N/A
Spyro: The Reignited Trilogy (2018)	Cannot see crater/source to determine fully	Appears as generic lava colours and degassing bubbles	Appears as generic rock colours/texture	N/A	Some particles are ash, most are cinders/embers	N/A	N/A	N/A

Table 1. Continued.

Subnautica (2018)	Realistic collapsed caldera spanning 2 km in diameter	Molten lava flowing underwater with no cooling effects	Well detailed pillow lava and pahoehoe textures	N/A	N/A	N/A	N/A	N/A
The Elder Scrolls: Skyrim (2016)	Unrealistically steep cone-shaped	N/A	Detailed basalt columns	Lacks convection complexity and detail. Small amount of drift available	No ash fall however, ash deposits are light grey coloured	N/A	N/A	N/A
The Legend of Zelda: Twilight Princess (2006)	Unrealistically steep cone-shaped	Realistic lava colours and textures with some cooling surfaces around the edges	Appears as generic rock colours/texture	N/A	N/A	N/A	N/A	N/A
The Legend of Zelda: Breath of the Wild (2017)	Unrealistically large, two-tiered caldera. The central vent is also ridiculously steep	Realistic lava colours and textures with some cooling surfaces in low velocity areas	Appears mostly as generic rock texture. However, some areas show dark, cooled lava flows	Generic dark, pixelated cloud radiating out in all directions a short distance from the central vent	Ash depicted as a ember-like particles rising in the air	N/A	N/A	N/A
The Shadow of the Tomb Raider (2018)	Realistic composite/strato island volcano	Realistic lava colours and textures with some cooling surfaces around the edges	Appears as generic rock colours/texture	Show major convection, one has indication of drifting due to wind direction	First volcano example has more light showering of ember-like particles. Second example is more fog effect	N/A	Realistic flow showing material to water ration rheology and power	N/A

4 Discussion

4.1 Overall volcanic representation

There is no doubt that volcanoes within video games provide entertaining, challenging and popular levels, appearing in numerous respected franchise COTS games. Because of this, millions around the world will ultimately become immersed within these volcanic landscapes (rich in real-world features) on a regular basis for a considerable number of hours.

What was found through playing such games is that there was no "perfect" game in regard to the portrayal of volcanic features. Each game had a mixture of realistic and unrealistic features (Tables 1 and 2; Fig. 10). In most cases of unrealistic features, they tend to be exaggerated, such as oversized stratovolcanoes and large volumes of lava being constantly produced (Table 1). Whilst this does result in very stereotypical landscapes that all people will be able to recognise as "volcanic", it could also lead to a false belief that all volcanoes are of this shape and always have lava flows pouring out of them, which is far from the truth (Siebert et al., 2015). These exaggerations may be included to improve the entertainment and excitement factor of the gaming experience, ruling that to be more important than making them more realistic (Hut et al., 2019).

When it comes to the representation of volcanic features in the minds of the wider public, lava flows are synonymous with volcanoes. From the orangey-red glow to the natural power lava flows hold, it is always one to captivate an audience. There is also the danger that lava flows pose. Burning at hundreds of degrees Celsius, lava flows can destroy anything in their path, creating a great risk factor that developers can readily implement into their games for an added level of difficulty. Taking all of this into account, it is easy to see why they are such a staple in COTS video games (Fig. 10). However, it is the comparison between the appearances of volcanic features to those of volcanic hazards that highlights a problematic area (Fig. 10), not only in the number of realistic to unrealistic encounters but also in the number of encounters overall. In total, there are 78 representations of eight common volcanic features (Fig. 10a), and of these, 35 are portrayed in a realistic manner. In contrast, there are only 31 representations of six common volcanic hazards (Fig. 10b), and only seven of them were realistically portrayed.

There are many potential reasons for developers focusing more on the visual aesthetics of a volcano than the hazards. One could be that the costs of implementing the damage mechanics are not seen as worthwhile. For example, PDCs are immense, catastrophic events that would require a great deal of animation development, potentially requiring a very dramatic moment of a story and even a cutscene to incorporate one. This would explain their low representation rate within the video games.

Another reason could be that as video game graphics are improving, especially in more modern video games, the de-

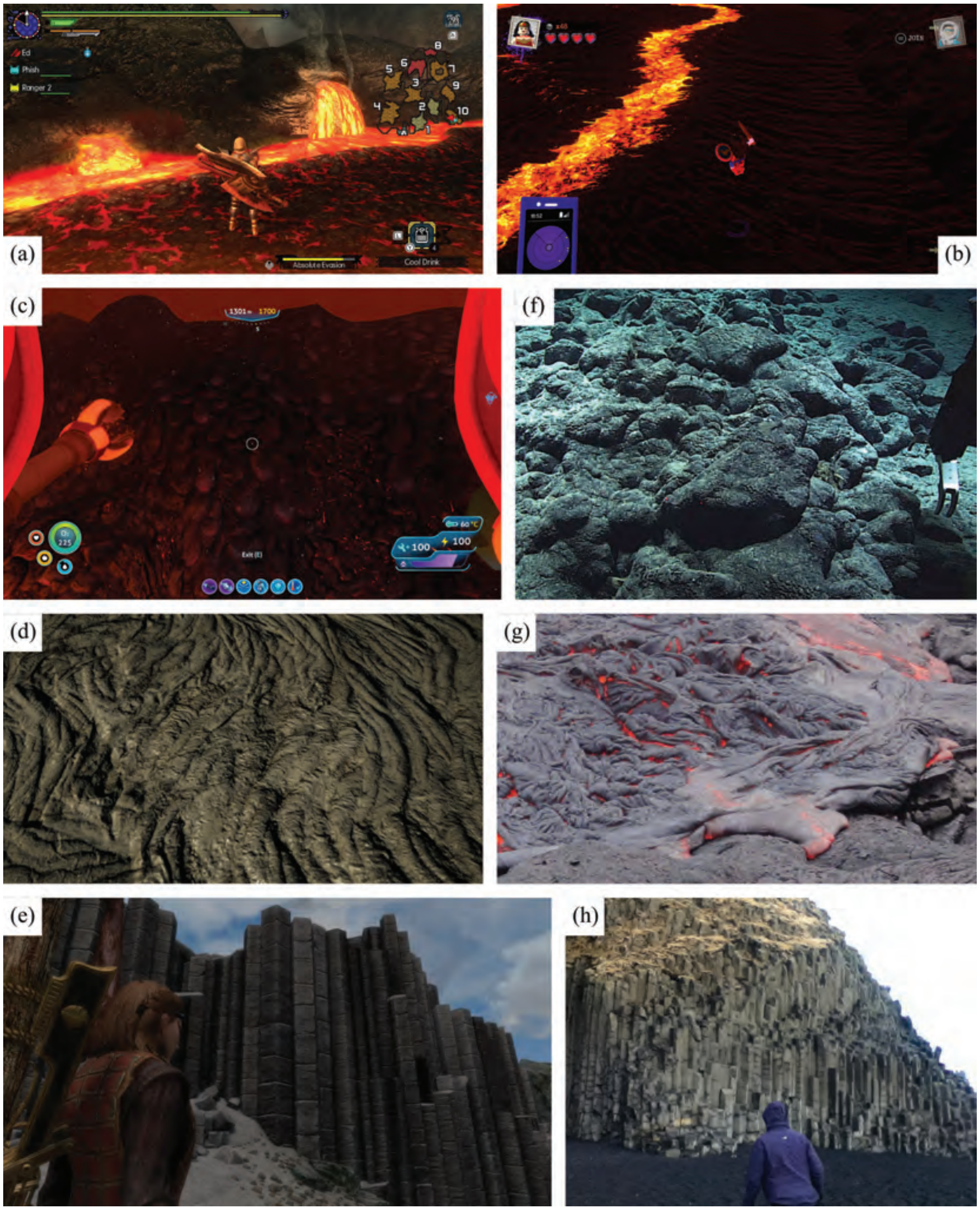

Figure 2. Lava surfaces in *Monster Hunter: Generations Ultimate* © Capcom (2018; **a**), ropey pahoehoe textures in *LEGO DC Super-villains* © TT Games Ltd (2018; **b**), pillow lavas in *Subnautica* © Unknown Worlds Entertainment (2018; **c**), more ropey pahoehoe textures in *Assassin's Creed Odyssey* © Ubisoft (2018; **d**) and columnar textures in *The Elder Scrolls: Skyrim* © Bethesda Game Studios (2016; **e**). Real-world examples of pillow lavas (Keoea Seamount, NOAA, 2015; **f**), ropey pahoehoe textures (Hawaii, Lis Gallant, 2013; **g**) and basaltic columnar textures (Iceland, Edward McGowan, 2014; **h**).

velopers want to focus on making the games more visually immersive, believing this is more important for players than their characters taking realistic damage.

The topics that would initiate the least amount of tangential learning, despite their importance within volcanological geoscience, would be towards tephra fall deposits and gas emissions, in particular the risks both of these ejecta can cause. This is owed to the poor representation of the two topics within the COTS video games (Fig. 10), with volcanic ash often only presented as a particle effect and nothing more. As a result, players would be more likely to forget about the volcanic ash, ignoring it in a style similar to "banner blindness"

Figure 3. The two-tiered caldera of Death Mountain in *The Legend of Zelda: Breath of the Wild* © Nintendo (2017).

(Hervet et al., 2010) instead of gaining an interest in volcanic ash and prompting self-education into how it is formed and the major health risks it poses to life (or even the environmental benefits). Volcanic gas emissions are most likely underrepresented due to their general colourless appearance, making them very difficult to visually implement within a video game environment. Therefore, it may be necessary to refocus the educational curriculum if COTS games are to be used to include more on volcanic ash and volcanic gas emissions to ensure a well-rounded knowledge of volcanoes and to develop the ability for students to self-analyse their observations, such as asking them to hypothesis real-world risks within games (Van Eck, 2006; Parham et al., 2011).

4.2 Incorporating learning within video games

In-game tangential learning is an extremely effective way to utilise COTS video games. For example, *Subnautica* (2018) has an in-game encyclopedia that registers information when travelling to certain biomes or obtaining materials. One such entry is about how the map is situated within the crater of an active caldera that collapsed thousands of years prior. With the use of in-game encyclopedias, players have the choice to access the information at any time, without having to stop playing at critical moments to actively research about the volcanic features they have just discovered. This not only provides easily accessible information but does not hinder the entertainment factor of the gaming experience (Van Eck, 2006; Floyd and Portnow, 2012a).

Another method observed is the use of non-essential, non-playable characters (NPCs) that players do not need to interact with to progress; however, if placed near an interesting feature, they can provide further information about it when spoken to. Within *Pokémon Emerald* (2005; Figs. 8a and 9), if players talk to NPCs on the slopes of Mt. Chimney or along Route 113, they will speak about the nearby active volcanic crater and the volcanic ash that it produces. However, it is vital that the information provided within the games are fac-

Figure 4. Underwater lava flows in *Subnautica* © Unknown Worlds Entertainment (2018).

Figure 5. Volcanic ash visual effects in *Pokémon Emerald* © The Pokémon Company (2005; **a**), *The Legend of Zelda: Breath of the Wild* © Nintendo (2017; **b**) and *LEGO Marvel Superheroes 2* © TT Games Ltd (2017; **c**).

tually correct; otherwise, players could take this information to be true (Parham et al., 2011). While the NPCs in *Pokémon Emerald* (2005) are very vocal about the falling ash, their lack of concern about ash-related health risks could easily lull players into a false understanding of real-world hazards.

Some video games have even made use of loading screens to add in quick facts while the player waits for the game to progress. These often cover game tactics and tips; however, they can also include information related to the setting of the game. For example, *Assassin's Creed: Odyssey* (2018) provides facts about Spartan history, Greek mythology, the culture and major events that all tie into the time setting of the game (Brouwers, 2018). However, just like the potential use of NPCs, it is vital that these quick facts are indeed factually correct. Otherwise, this would become another situation where commercial games would instil false understanding in players.

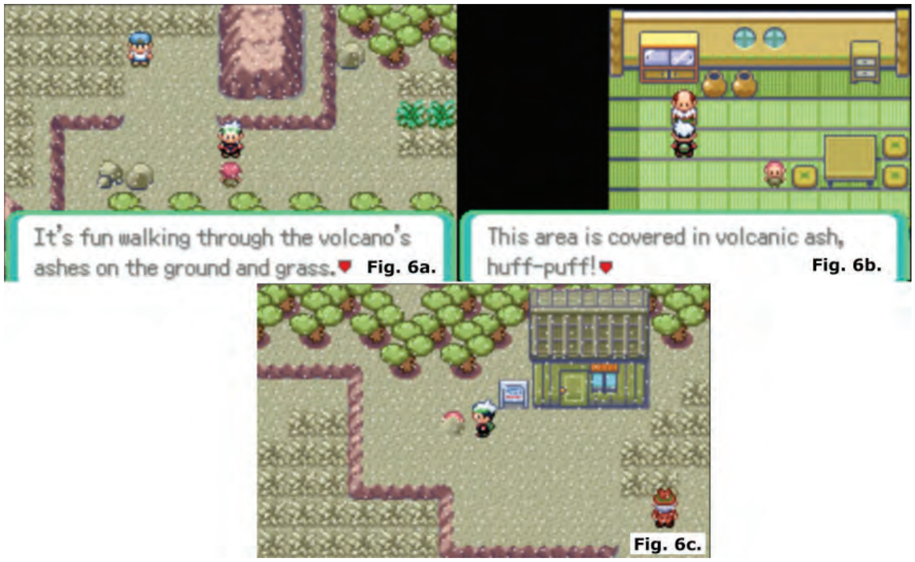

Figure 6. The effects of volcanic ash from the volcano Mt. Chimney on local residents in *Pokémon Emerald* © The Pokémon Company (2005).

4.3 Impact of incidental learning

Incidental learning has a greater impact on erroneous learning with players unconsciously picking up details about volcanoes, such as the underwater flowing lava in *Subnautica* (2018), and without any direct in-game tangential learning mechanisms to correct them; they could easily believe these errors to be factual. Repetitive erroneous incidental learning from non-traditional sources such as video games has statistically proven to lower the level of one's understanding about volcanic systems (Parham et al., 2011).

4.4 Utilising video games within geoscience

A potential use in the education system could be to employ a style of facilitated learning. Differing from the other types of learning previously mentioned, facilitated learning encourages the students to take more control of their learning with the teachers providing resources and getting the students to discuss the situation themselves with minimal guidance. COTS games would act as the resource, and the teachers could set assignments to students to play through similar video games and test their knowledge by getting them to assess the realism of the features found (Van Eck, 2006; Mohanty and Cantu, 2011), similar to what was done in this investigation. The idea of asking students to play a video game instead of reading a textbook would certainly prove to be more popular and therefore potentially lead them to become more invested in their studies, while also improving their critical thinking skills (Parham et al., 2011; Hobbs et al., 2019). While COTS games have the potential for driving tangential learning, providing students with a little guidance would provide even greater benefits by discussing and reassuring them that they are on the right path.

How different COTS video games are utilised within the education system would greatly depend on the age of the intended audience, their mentality to learning and their required curriculum. Examples of how COTS games can be utilised are as follows. Children-friendly games such as *Minecraft* (2009), which have access to multiplayer environments, can make for the perfect type of game to get students within primary education interested in geoscience. The open-world setting would allow the young students to transverse a pre-made volcano in a group, letting them explore and show their peers different volcanic features that they find. The lessons would therefore be primarily led by students, with prompts from the teacher that direct students to key features when necessary. Maps on *Minecraft* (known as "seeds") can also be shared with others, meaning the different volcanic or geological maps could easily be distributed to numerous institutions.

Within secondary schools, COTS games can be used as homework tasks, where the student is asked to find an example of a geological feature within a COTS video game of their choice and then have to write a short piece on their findings. Such tasks would allow the students to think outside the box with their learning and apply what they have been taught in the classroom to a very different setting. The open choice of video games means that students do not have to gain access to particular games and instead even use free-to-play games. Teachers as well would not have to make dramatic changes to their lesson plans as students would be playing the games at home, and yet this would allow said teachers to assess an in-

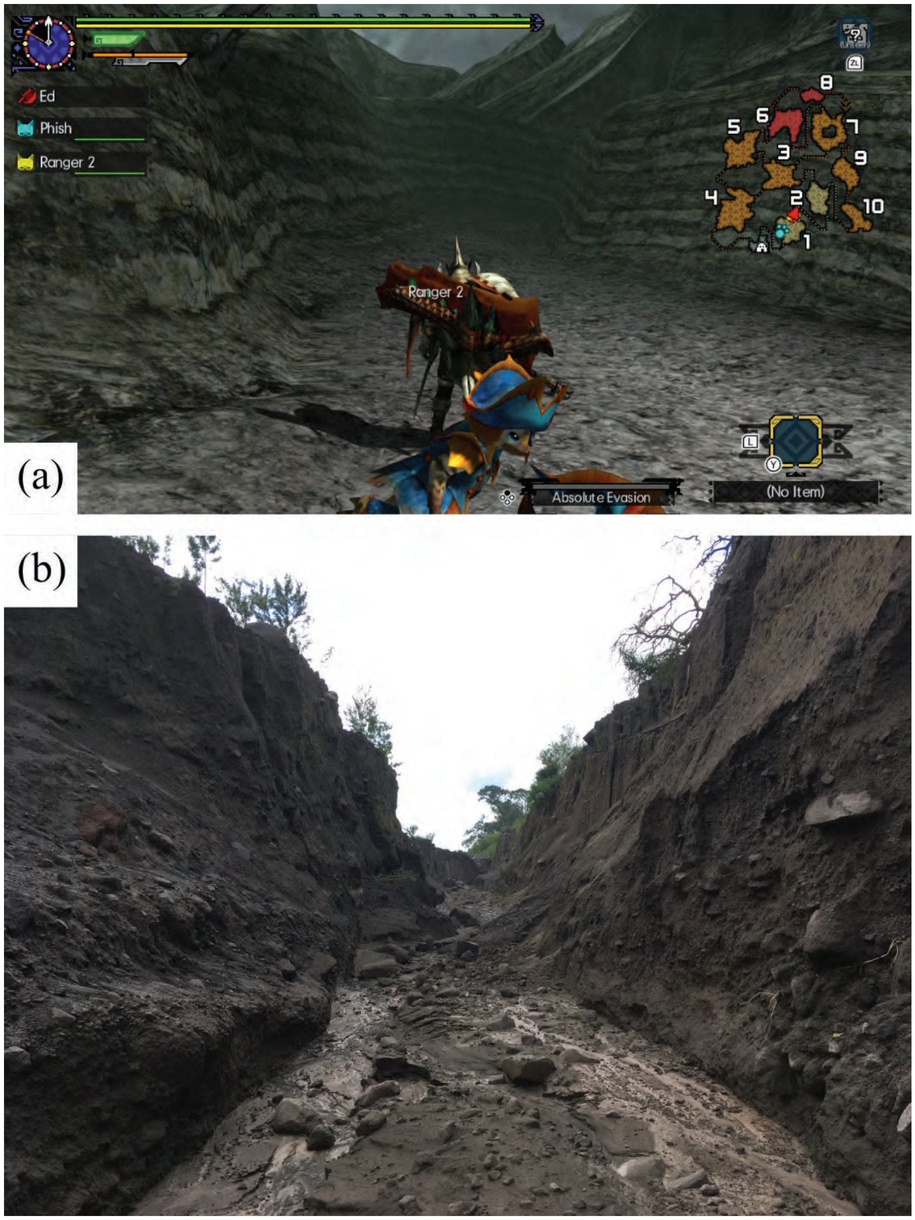

Figure 7. Art design of potential PDC deposits in *Monster Hunter: Generations Ultimate* © Capcom (2018; **a**) compared to a real-world example of a dissected pyroclastic density current in Mexico, created by the Volcán de Colima eruption in 2015 (Edward McGowan, 2018; **b**).

dividual student's understanding of geoscience based on the work produced.

At a tertiary level (university or college), COTS games can be applied to a wide range of scenarios as the style of education becomes more dependent of the students themselves. Multiplayer games can be used as a form of group-based projects, with each group being given a different game. The task would be for the students to work together to interpret geological features found within the games, interpret their formation (backed up with real-world examples they have researched) and then compile their findings into a group presentation. Single-player games can be used for individual report-based coursework, acting in a similar way to the group-based project, where a student would instead write their findings up as a report to be marked by their assessor. This would be similar to the common "field-based mapping" project that many students experience at university, even possibly acting as an additional alternative to the recently developed "virtual field trips" by the University of Leeds (Houghton et al., 2015) and Imperial College London (MacKay, 2020). Such programs have been designed for stu-

Table 2. A summary of volcanic hazards in individual COTS video games. Features are colour-coded based on if they are realistic (green), unrealistic (orange), or both realistic and unrealistic (blue) and if there was insufficient data to determine accuracy (yellow) or not applicable due to no examples (N/A; white).

Video Game	Volcanic Hazards					
	Molten Lava	Ash Fall	Volcanic Bombs	Volcanic Gases	Lahar	Pyroclastic Density Current
Assassin's Creed: Odyssey (2018)	Players can stand on the lava and take fire damage before dying	N/A	N/A	N/A	N/A	N/A
Crash Banicoot N. Sane Trilogy (2018)	Players take burn damage three times and then disintegrate	N/A	N/A	Small geothermal vents are present and take burn damage similar to the molten lava	N/A	N/A
Hot Lava (2019)	Players slowly sink into the viscous lava and vision whites out before level is reset	N/A	N/A	N/A	N/A	N/A
LEGO DC Supervillians (2018)	Depending on the character, take damage until being destroyed	N/A	N/A	N/A	N/A	N/A
LEGO Marvel Super Heroes 2 (2017)	Depending on the character, take damage until being destroyed	No mention, or concern expressed towards the constant falling ash	Depending on the character, the bombs are one-hit kills	N/A	N/A	N/A
Minecraft (2009)	Quick over-time damage dealt. High viscosity makes escaping difficult. Fire-damage still dealt afterwards	N/A	N/A	N/A	N/A	N/A
Monster Hunter: Generations Ultimate (2018)	Burn-damage dealt when standing too close to molten lava	Ash is blown away from accessible areas	N/A	N/A	N/A	N/A
Pokémon Emerald (2005)	Numerous people standing on the flanks of an active volcano, all the way up to the summit, in hopes of seeing it erupt	Some locals experience breathing difficulties. Vegetation covered in ash fall. Very limited concern with locals about the hazards the ash presents, as even children play in ash piles	N/A	No mention, or concern towards the volcanic gases when lava is clearly degassing next to people	N/A	N/A
Pokémon Silver (1999)	Pushing boulders into lava from a height within a public building causes no concern or harm to people standing within the splash-zone	N/A	Volcanic bombs block off access along a route. Locals are shown to be concerned. However, the bombs are located a considerable distance from the volcano	No mention, or concern towards the volcanic gases when lava is clearly degassing next to people, within a building that shows no ventilation systems	N/A	N/A
Sea of Thieves (2018)	N/A	N/A	Large bombs if on target, are one-hit kills. If off target, take damage	N/A	N/A	N/A
Spyro: The Reignited Trilogy (2018)	Player takes burn damage three times, turns black from burns and then slowly sinks into the lava	N/A	Non-hazardous to the player, but can be used as a weapon to one-kit kill enemies	N/A	N/A	N/A

Table 2. Continued.

Subnautica (2018)	Low damage over-time dealt, even when swimming through the lava. Also, no change in viscosity when moving from water to lava and back, so players can easily escape	N/A	N/A	N/A	N/A	N/A
The Elder Scrolls: Skyrim (2016)	N/A	N/A	N/A	N/A	N/A	N/A
The Legend of Zelda: Twilight Princess (2006)	Player sinks into the lava very quickly. However, this is reasonable given the heavy inventory carried. Wooden equipment is destroyed. Relatively low damage dealt after respawn	Ash fall appears to be of no concern to local non-humans. However, this could be an evolutionary trait. Humans avoid the area until eruption subsides	Being hit by a lava bomb does reasonable health damage, scaled to the size of the bomb. Largest bombs can one-hit kill	N/A	N/A	N/A
The Legend of Zelda: Breath of the Wild (2017)	Player sinks into the lava very quickly. However, this is reasonable given the heavy inventory carried. Relatively low damage dealt after respawn	Ash fall appears to be of no concern to local non-humans. However, this could be an evolutionary trait. Humans avoid the area until eruption subsides	Being hit by a lava bomb does substantial health damage. Also, locals fear the economic damage of the eruption as tourists are too scared of the lava bombs to visit	N/A	N/A	N/A
The Shadow of the Tomb Raider (2018)	Player 'disappears' and instantly dies	A possible mixture of ash and gases cause slow breathing damage before dying. Inconclusive as cannot determine the cause	N/A	A possible mixture of ash and gases cause slow breathing damage before dying. Inconclusive as cannot determine the cause	Player is insta-killed from the debris within the flow and swept away	N/A

dents who are unable to go into the field for personal reasons (e.g. disabilities or health risks).

Public outreach is becoming increasingly important within the geoscience community, forming a core component of many geological societies, such as the Geological Society of London, the European Geosciences Union (EGU) and the American Geophysical Union (AGU) to name a few. However, while using traditional methods of publicly accessible peer-to-peer exchanges such as talks or presentations can prove effective, it is becoming evident that new, more modern methods may serve to enable wider public communication (Research Councils UK, 2008; Redfern et al., 2016; Stewart and Lewis, 2017). This is where video games can be used to attract the public, using a medium they already understand and enjoy, and allow them to directly engage in geoscientific learning through playing. When attending events such as science fairs, members of the public can be given controls to individual games, allowing them to explore while geoscientists explain different features that are shown in a setting they are more familiar with. Single-player games with open worlds, such as *The Legend of Zelda: Breath of the Wild* (2017), would serve as a perfect example to use, as the public would be free to roam, and the lack of objectives means that can come and go as they please without a feeling of pressure to complete the level. More COTS video games are also being developed for virtual reality (VR). If outreach events were to utilise such VR games, players could become fully immersed within a geological setting, giving them a more hands-on experience than having to stand by and listen to complex geological information from a presenter. The experience can even enable tangential learning as they can conduct follow-up research after the outreach event (Mohanty and Cantu, 2011; Mani et al., 2016). The greatest benefit of using COTS video games in this circumstance is that they have already been designed to be accessible and understandable for a large audience by communicating information with less technical jargon in an engaging manner, which is how geoscientific information for the public needs to be presented (Donnelly, 2008; Stewart and Lewis, 2017). In regard to volcanological geoscience, many people do not have easy access to active volcanism, making COTS games an incredibly accessible way for people to interact with it in a relatively cheap (compared to costs involved in travelling to the site), engaging and safe approach (Oblinger, 2004).

Figure 8. Lahar sequence in *The Shadow of the Tomb Raider* © Eidos-Montréal (2018; **a–d**) compared to a still image of a lahar in full flow down a barranca at the base of Volcán de Colima, Mexico (Edward McGowan, 2018; **e**).

Figure 9. Tephra and volcanic haze visual effects in *The Shadow of the Tomb Raider* © Eidos-Montréal (2018).

4.5 Considerations with implementing video games within geoscience education

The implementation of video game learning is not without its hurdles. People would need to be mindful that many COTS games and the devices that operate them are expensive, and many people might not have access to them. This is certainly a concern with more modern games that are becoming increasingly more expensive to purchase due to the higher development costs to make the games more immersive. Considerations must also be taken into account in regard to the

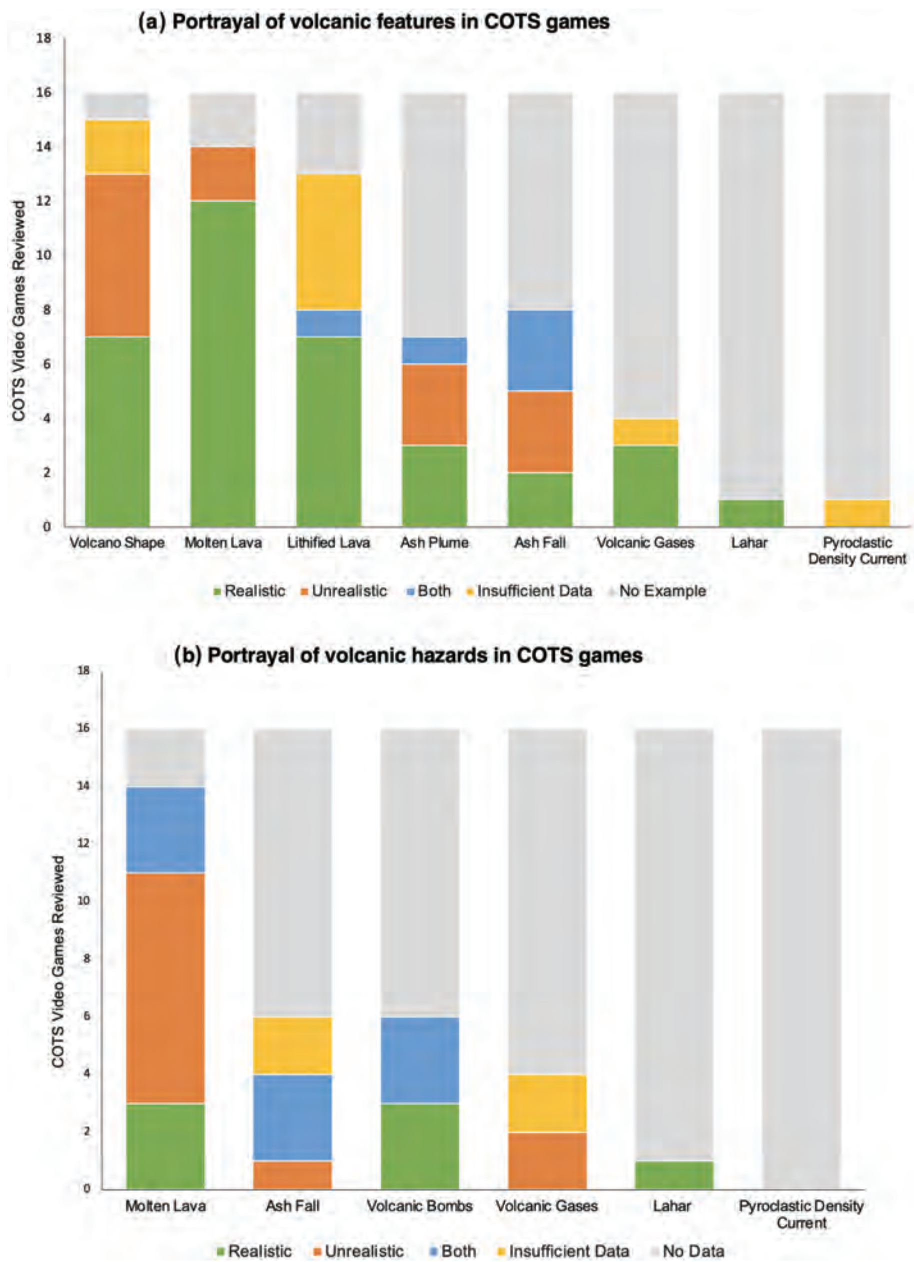

Figure 10. The count of volcanic features **(a)** and of volcanic hazards **(b)** found within the COTS video games reviewed, displaying whether or not they were portrayed in a realistic or unrealistic manner.

age ratings assigned to each game. The games we reviewed covered a range of age ratings, showing that there are games suitable for all, such as *Pokémon Emerald* (2005), which has an age rating of 3+ and so would make it suitable for primary education level teaching. However, *The Shadow of the Tomb Raider* (2018) has an age rating of 18+, meaning it would not be suitable for educational purposes for students until tertiary level.

There are also many cultural and social factors that influence gaming experiences and therefore the educational experiences as well. One example would be a player's familiarity with both gaming in general and towards specific gaming titles or genres. For those who have more experience with playing COTS games, they will have an advantage with understanding the game mechanics, controls, level set-ups and more. This advantage could make learning through video games more appealing to individuals. In contrast, those who are unfamiliar with gaming could find such tasks difficult and so become a less appealing method of learning (Pringle et al., 2017). Also, if the teachers are not familiar with playing video games, they may have to spend a number of hours familiarising themselves with gameplay and testing the games to see if they are suitable for their teaching purposes before using them (Gros, 2015). As a result, video games could be seen as too much effort to implement to some educators.

Another consideration would be the ease of accessing particular areas within the video games. *Monster Hunter: Generations Ultimate* (2018), for example, takes a considerable number of hours of gameplay in order to reach the levels that allow players to visit the volcano. Therefore, to save students from having to spend unnecessary time trying to reach particular areas, games would have to be chosen that have direct access from the start, or game saves that have unlocked said areas would be required for easier implementation.

5 Conclusion

Commercial off-the-shelf video games contain a wide range of volcanic features, including lava flows, volcanic ash, lava bombs and even lahars, allowing millions around the world to interact with them in an entertaining environment outside of academia that could induce tangential learning.

As expected, these commercial games have a mixture of accurate and inaccurate features, with none showing to be flawless. Because of this, the use of COTS games for tangential learning should be done with caution. That is not to say it should be rejected entirely. Accurate features could be used within geoscience, particularly in regard to outreach work with the general public to capture an audience's attention without presenting misleading information or to teach about volcanic hazards in a risk-free, engaging environment.

The inaccuracies within the video games tend to be over exaggerated in order to increase the entertainment factor, either by creating stunning landscape visuals or increasing the risk factor to provide more of a challenge for players. While this could lead to a lack of true understanding towards volcanic systems, advantages can be taken away from this. One would be to put a greater focus on volcanic hazards such as volcanic ash, volcanic gases and pyroclastic density currents, which are all areas that are wildly inaccurate at times or even non-existent and therefore likely to be forgotten or overlooked by students. The other advantage would be to think in terms of tangential learning. The landscapes may be over-the-top scenes at times,but they are also enticing to look at and admire. Through enticement, players could be drawn into the appeal of volcanoes and take to other forms of learning platforms to teach themselves more about features they find within the games. Education systems could also take advantage of this and use the inaccuracies within the video games as tasked assignments through facilitated learning methods. Students could be asked to play through the games, find as many features as they can and comment on their realism.

While the extent of learning through playing COTS games is still unknown, the first part of our investigation has shown that these video games could indeed prove to be a useful source for future education for the masses (both within academia and in outreach projects). The second part of the investigation on the learning potential of COTS games for volcanology will be to explore what people do learn. With further investigations assessing the direct impact on players, there is an opportunity to correctly assess how to incorporate the use of COTS games in geoscience.

Data availability. All data was collected through playing individual video games. We do not have permission from the developers to share free access to each game. However, they are all publically accessible to purchase.

Video supplement. Video Supplement 1: ash particles in the air around Death Mountain in *The Legend of Zelda: Breath of the Wild* © Nintendo (2017), https://doi.org/10.5446/50063 (McGowan and Scarlett, 2020a).
Video Supplement 2: player being hit by a lava bomb and instantly dying in *Sea of Thieves* © Rare Ltd (2018), https://doi.org/10.5446/48881 (McGowan and Scarlett, 2020b).
Video Supplement 3: two sequences of Lara (played character) trying to escape a lahar that rushes past her in *The Shadow of the Tomb Raider* © Eidos-Montréal (2018), https://doi.org/10.5446/50064 (McGowan and Scarlett, 2020c).

Author contributions. EGM and JPS conceptualised the project and developed the methodology together. EGM carried out seven full game reviews, and JPS carried out five full and four partial game reviews, with both validating the results together. JPS prepared the figures for the article. EGM prepared the draft and editing of prepublication manuscripts with contributions from JPS.

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BOOK REVIEWS

Book Review: *Playing Nature: Ecology in Video Games.* Alenda Y. Chang. Minneapolis: University of Minnesota Press, 2019. ISBN 145296226X

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Alenda Y. Chang's *Playing Nature: Ecology in Video Games* (2019) is a timely revelation for those scholars who, like myself, enjoy seeking the increasingly clearer links between new media genres and ecocritical thought. It can also be proposed as an environmentalist guideline for game designers who seek, in the author's own words, "to create meaningful interaction within artificially intelligent environments, to model ecological dynamics based on interdependence and limitation, and to allow players to explore manifold ecological futures – not all of them dystopian" (16). Chang's wide repertoire of video games that incorporate human and nonhuman interactions from an environmental perspective displays her depth of knowledge interwoven through the Introduction and the following five chapters. With the breathtaking gameography of almost seven pages, the book aptly balances the environmentally oriented products of the gaming industry and the theoretical discussions presented by well-known ecocritics in our present era. Penned diligently and delicately, *Playing Nature* indicates a mastery of bringing together "the Earth itself, its atmosphere, and our bodies," which Chang compellingly argues, "are media through which countless other things pass" (235).

Chang 'playfully' opens her Introduction, secondarily entitled "Edge Effects," with an epigraph quoted from Donna J. Haraway, underlining the unexpected power of the realm of play in making possible "worldliness and recuperation" (1). The author then turns our attention to *Walden*, a video game that derives its name and protagonist from Henry David Thoreau and his famous work. With the *Walden* example, she problematizes our relationship with nature and technology and points out the critical attitudes towards both: "Technology, particularly electronic technology, figures as the apotheosis of either human megalomania or human ingenuity, depending on your attitude toward post-industrial capitalism, while nature historically has oscillated between being that which is (terrifyingly or reassuringly) beyond human control and that which

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is subject to such control" (2). Using this observation as her springboard, she acknowledges how nature and culture are actually indivisible and sets the aim of the book by stating that it seeks to bridge the conventional divide between nature and culture through her analysis of games via an ecological perspective. The most remarkable point made in the Introduction is perhaps when the author invokes the concept of "anthromes" as a signifier moving humans from a disturbing element in otherwise perfectly balanced nature to an always already embedded system within natural ecosystems. Thus, she builds links between the naturecultures of this planet, which have narrative qualities, calling to mind the material-ecocritical approach to "storied matter," as coined by Serenella Iovino and Serpil Oppermann, and the culture of gaming in all possible genres, which involves a set of interactive agencies, both human and nonhuman. The entangled relations of games, players, and play contexts, therefore, serve as Chang's template for discussing the recent academic theories in relation to ecocriticism and ecological thought.

The first chapter, "Mesocosm," starts with a boundary-blurring distinction between real and imaginary environments. Exceeding the experimental enclosures in lab environments, mesocosms are a source of inspiration for the author's characterization of gameplay and player experience as more than "virtual" reality. This chapter discusses the mesocosmic qualities of games from different decades and of various formats. In most games, the author notes, the designers often fall into traps such as leaving the environment as mere background scenery or depicting it as a tool for extraction of natural resources on whose capacities the player's game life depends. She argues that while player agency is significant, "more environmentally realistic games could enhance our understanding of real-world environmental issues (not just crises), either by implicitly or explicitly modeling different forms of our individual and collective environmental agency" (23). After discussing the game *Adventure* in terms of its ecomimetic qualities, Chang investigates thatgamecompany's *Flower* as an environmentally oriented text and analyzes the game by making additions to Lawrence Buell's criteria in *The Environmental Imagination*. She underlines that, in addition to Buell's four principles, an "ideal environmental text produces involvement" (32), turning to an analysis of several games, ranging from *World without Oil* and *Black Cloud* to *Pokémon Go* and *Play the LA River*. The chapter concludes with the rightful claim that "environmental gameplay also permeates offline, educational, and built environments" (67). As Chang proposes, such transmediatic effects of ecological thought and games on one another, I believe, exemplifies the 'intra-active relations,' to borrow Karen Barad's term, between digital, offline, natural, and built environments.

Perhaps because I was less familiar with the concepts, games, and names in "Scale," I found this second chapter the most difficult to read and follow, although it evidently contributed no less than the other chapters to Chang's overall argument. In this chapter, Chang notes that there are strong links between "environmental thinking" and "scalar understanding" in the sense that the former is "an exercise" in the latter (70). She argues that "games are tailor-made to develop scalar environmental consciousness" as they close the gap between the local and the global, approximating the macro and micro domains, concluding in this chapter that games may serve a "pedagogical function" in showing us the links between the human and the nonhuman spheres (105).

That said, Chang brings us to her third chapter, "Nonhuman," which opens with a reference to Jacques Derrida's famous lecture where he narrates his experience of shyness over his naked body in the gaze of his cat. From this point, Chang links her argument to games that present the player with a chance to have or grasp animals' perspective. She discusses the attempts to design games that try to break away from the long tradition of anthropocentrism, with "animal- and plant-based nonhuman representation" (124), after which she dedicates the rest of the chapter to "nonliving stuff" or "bit narratives" which "typically either feature computers or digital objects as protagonists or meditate on themselves as digital creations" (124). Since the author builds this chapter on her entangled discussions of the 'it-narratives' and the 'bit-narratives,' that is, she incorporates literary scholarship into game studies within an array of ecological perspectives, I found "Nonhuman" the most intriguing chapter of the book. The concluding words of the chapter are brilliant in supporting Chang's material-feminist-ecocritical viewpoint. "Humans," she writes, "are not distinctive but are rather assemblages of human and nonhuman elements, exemplified by the trillions of bacteria cells that compose our gut microbiomes" (144). This posthumanist perspective is outlined best when the author notes that "humans are also not simply thinking 'interiors' opposed to environments 'out there' or outside ourselves" (144), hinting at a "viscous porosity," as Nancy Tuana would call it, of human and nonhuman bodily environments.

From thermodynamics to electronic waste, the fourth chapter entitled "Entropy" touches upon many critical issues that are inherently ecocritical, and therefore, proposes a more posthumanist sense of entanglement, which might, aside from quantum physics, also fall into the scope of cybernetics, computing and machine intelligence, and overall, systems theories. Chang strongly displays this posthumanist tendency without using the word 'posthuman' when she writes: "To focus on environmental matter is not to exclude the human, but to decenter it, to reverse the figure/ground relationship that typically holds between individuals and worlds" (147). She also asserts her purpose as follows: "to demonstrate that economic and environmental concerns are always intertwined" (147). She discusses these issues via the lens of farm games such as *FarmVille*, *Farm Craft*, and *Farm Craft 2: Global Vegetable Crisis*, while invoking a blend of various ecocritical concepts such as environmental degradation, limitation, Latourian ecological economics, and Timothy Morton's dark ecology.

The final chapter, "Collapse," like all the other chapters, has a telling title and it deals with games that have dystopic, catastrophic, postapocalyptic, or worst-case scenarios. In this chapter, the author discusses, again, several games from an ecocritical perspective with a possible pedagogical value. She proposes that instead of simply critiquing such games for anthropocentric representation and crude violence, one might view them as opportunities for "education," "disaster preparedness," "emotional catharsis", and "pleasurable amoral aggression" (194). She exemplifies this and supports her stance by referring to especially *World of Warcraft*'s 2010 expansion *Cataclysm* and *SimCity*, while she also touches upon several other examples like *Super Mario Bros.* and *Prince of Persia*. The concluding lines of this chapter also display an overall closure for the book as the author notes: "We cannot afford to ignore the ecology of games" – and "games of all kinds" in a time of climate change. Chang's powerful words can only describe how I felt after reading this book; we cannot take games for granted. "This may be our one chance to live, and play, deliberately" (235).

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4. *Volcanoes in video games: the portrayal of volcanoes in commercial off-the-shelf (COTS) video games and their learning potential* (McGowan & Scarlett, 2021)
5. *Book Review: Playing Nature* (Ağın, 2021)

Case Studies

Conway's Game of Life

*Figure 12 - *GIF* https://en.wikipedia.org/wiki/Conway%27s_Game_of_Life*

Conway's Game of Life was created by John Horton Conway in 1970 and is popular amongst the mathematicians, programmers, and game designers. The game is played out by a computer on a grid of white tiles which are considered 'dead', and black tiles which are considered alive. There are three rules that play out each frame: 1. a living tile with fewer than two living neighbors dies, 2. a living tile with two or three living neighbors lives on to the next frame, 3. a living tile with more than three live neighbors dies. Patterns emerge from the sequence of played frames and are documented online by fans.

There are many variations on creating and playing *Conway's Game of Life*. The typical method to play is by placing a few live tiles, as though painting across the screen, and watching how they transform and inevitably find a looping pattern or disappear entirely. It is minimal to the core, yet there is unpredictability and unknown behaviors, possibly mimicking a natural ecosystem. Conway's game serves as a wonderful case study on how user input and a basic set of rules can potentially influence environment centered game play.

This example relates to a topic of study known as cellular automata, a concept within automata theory. Cellular automata are mathematical models which may be applied in computation software to create systems of many components which have complex behavior via a set of rules. Conway's game features this through its three definitive rules. Cellular automata's emergence and creation of patterns can be further studied in game design to apply it as a unique visual and interactive medium within games. *Conway's Game of Life* goes beyond being a game and becomes a simulation that bridges mathematical theory to a metaphor for complex living systems.

Old School RuneScape

Figure 13 - https://oldschoolrunescape.fandom.com/wiki/Farming

Old School Runescape was just called *Runescape* when I played the massively multiplayer online role-playing game. This was back in my middle school days; I played the free version where I found myself often fishing and woodcutting to raise my gold amount. Inevitably, *Runescape* updated its graphics and gameplay to evolve the experience, and despite the effort, there was a declining player population. This ‘updated’ version was released July 2013 and would be known as *Runescape 3*. The game developer, Jagex, decided to release an August 2007 version of the game after acknowledging the shift of gameplay and creating an online poll which overwhelmingly supported the idea of supporting *Old School* (also known as *Runescape 2)*. It has turned out that *Old School* is a more popular platform and frequently has a bigger audience on streaming sites such as Twitch.

Besides the interesting fact that a low fidelity game retains its popularity (it could also be a case study for a game developer’s healthy relationship to the player community), I’d like to share it as a case study for its array of non-violent skills in an open world. The core premise of

Old School is starting out with a wide range of violent and non-violent skills at level 1 and being able to raise them to 99. If a player obtains an axe, they can cut down some a basic tree in the starting area. As they cut down more trees, they're woodcutting level will rise. This opens the option to cut down other trees, such as oaks and willows. Each tree regenerates after a certain amount of time and depending on the tree, a player may get one to a few logs which they can sell. The logs themselves can be used for building fires to cook food, crafting compound objects, construction, and more. The same logic and systems apply to other skills such as fishing and farming. A player who is fishing will only be able to receive certain fish depending on the type of body of water. In applying real life principles to becoming skillful in-game, Jagex indirectly educates its player base on environmental conditions. Players become aware of ecological nuance through available interactions. Jagex continues to add skills to *Old School* (the latest being sailing) which they develop alongside the player community through polls and frequent blog posts.

Baba is You

*Figure 14 - *GIF* https://techcrunch.com/2019/03/14/ape-out-and-baba-is-you-demonstrate-the-depth-of-simplicity/*

Baba is You was created by Arvi Teikari as a short demo in 2017 for a game jam. The game was later expanded and released in 2019 for PC and Nintendo Switch. It is a puzzle game that features an unconventional game mechanic where the player can push rules around and together to manipulate the environment and solve visual riddles. The rules appear as text tiles and the character, Baba, moves them as seen in the example above. Baba pushes the tile 'ROCK' until it connects into the statement "ROCK IS YOU", at which point the player embodies the actual rock on screen and moves around. *Baba Is You* depicts how altering the environment can change the player's relationship with the game world. This mechanic can be applied to environment centered gameplay to expand the role of rules in the game space.

Each object in an environment can have a set of rules, and a player might move them around as if they were gardening or maintaining the landscape. Engaging with this sort of sandbox-like game could allow players to experience ecosystems in their delicateness. This would be a reflection on consequences and tradeoffs, encouraging players to pause and think through their decisions before speed running to the end of the game. How they engage with the world will alter and affect the gaming experience. Depending on the goal of the game experience, a player might need to start over to correctly solve a puzzle.

Design Conjecture

In this conjecture, I imagined myself creating a *Baba Is You*-like game that allows the player to select objects (note the white outline on a flower) and move them around. After placing them down, they will evolve according to their rules. In this case, I imagined the player picking up a sapling and moving them close to the water. If next to the water, then the sprout will flower. A time element would be applied so that the sprout does not immediately flower. This can be seen as an open world gardening sand box game.

I plan to create a vignette of this project for play testing, to analyze exactly how players interact with the experience. It is important that I gather feedback to direct the experience and understand what the player's goal might become.

Figure 15

Figure 16

Further Readings

1. *A Procedural Critique of Deontological Reasoning* (Togelius, 2011)
2. *A Realistic Reaction System for Modern Video Games* (Katchabaw, 2005)
3. *As the yellow rattle ripens': Gardening craft as socio-ecological place-making* (Cele, 2023)
4. *Back to the Virtual Farm: Gleaning the Agriculture-Management Game* (A. Y. Chang, 2012)
5. *Bonding with Horses and Other Animals in Breath of the Wild* (Seraphine, 2018)
6. *Bridging anthropological theory: Accumulating and containing wealth in World of Warcraft landscapes* (Root, 2023)
7. *Compact Nature: The Role of Playing and Learning Gardens on Children's Lives* (*Compact Nature: The Role of Playing and Learning Gardens on Children's Lives*, 2024)
8. *Computer Games as Intelligent Learning Environments: A River Ecosystem Adventure* (Tan et al., n.d.)
9. *Constructionist learning through serious games* (Chan, n.d.)

10. *Game Mechanics Integrated with a Lindenmayer System* (Fornander, n.d.)
11. *Gaming as Everything: Challenging the Anthropocene through Nomadic Performativity* (Butucea, 2020)
12. *Gaming Green: The Educational Potential of Eco – A Digital Simulated Ecosystem* (Fjællingsdal & Klöckner, 2019)
13. *Good ethics cannot stop me from exploiting: The good and bad of anthropocentric attitudes in a game environment* (Ho et al., 2022)
14. *"Magic Flowerpot": An AR Game for Learning about Plants* (Zarraonandia et al., 2019)
15. *Playing farmer: At the intersections of neo-liberal capitalism and ecocriticism in Stardew Valley* (Crowley, 2023)
16. *Playing in the Virtual Sandbox: Students' Collaborative Practices in Minecraft* (Davis et al., 2018)
17. *Playing with Nature: On "Tears of the Kingdom" as Ecofiction* (Dolan, n.d.)
18. *Research Article: Using Simulation Games to Teach Ecosystem Service Synergies and Trade-offs* (Verutes & Rosenthal, 2014)
19. *Serious games on environmental management* (Madani et al., 2017)
20. *The garden of virtual delights: virtual fauna for a botanical garden* (Martins et al., 2013)
21. *The Joystick in the Garden: Video Games, American Studies, and Politics* (Mayar & Schubert, 2021)
22. *The Order of Play: Seeing, Teaching, and Learning Meaning in Video Games* (Hung, 2009)
23. *The potential for using video games to teach geoscience: learning about the geology and geomorphology of Hokkaido (Japan) from playing Pokémon Legends: Arceus* (McGowan & Alcott, 2022)
24. *The sinking garden* (Yang et al., 2020)
25. *Toward Defining and Assessing Creativity in Sandbox Games* (Rahimi et al., 2023)

26. *Video games as a tool for ecological learning: the case of Animal Crossing* (Coroller & Flinois, 2023)
27. *Virtual gardening: Identifying problems and potential directions for 'ecological awareness' through soil management and plant recognition gaming* (Lelièvre et al., 2020)
28. *Virtual reality for ecosystem dynamics education* (Arns et al., 2006)
29. *What Can Play: The Potential of Non-Human Players* (Stone, 2019)
30. *Within the Mainstream: An Ecocritical Framework for Digital Game History* (Backe, 2017)

Topical Section 3: Immersion

Section Introduction

The last section of this handbook intends to expand the definition of immersion via the environment centered mindset. Immersion is in many ways the sum of the previous two topical section titles. "Interaction" looks at rules and behaviors between player and environment, and "Visual" considers how different aesthetic qualities can serve function to game rules or player's imagination. Immersion in this handbook is discussed broadly. Some of the subtopics that will be discussed are immersion for restorative effects, infinite games, audio, walking simulators, and gamified focus media. In one way or another, I align these subtopics and discussed examples to ecological properties.

The literature in this section examines various types of immersion in media and how they might offer restorative effects through virtual nature simulations. The four papers specifically target immersion in relation to full-body experiences. I'm less interested in these four papers as I organize the handbook altogether and am more interested in the other content within this section. The book review of *Finite and Infinite Games* opens the conceptual question of play through infinite possibilities which is tangential to immersive experience while remaining on theme as environments themselves contain countless possibilities.

Within, you'll find many examples that do not seem to have dark pattern conditions. Dark patterns are apps or software that trick users into doing something, usually repeatedly. The games in the case studies and my conjecture are the antithesis of dark patterns and encouraging of immersion in a manner that supports breaks as well as rethinking games as slow interactive media. *Electroplankton*, *Death Stranding,* and *Mountain* engage players in sensorial and emotional aspects. *Electroplankton* is a game that blends artistic expression with audio from sound-producing plankton. *Death Stranding,* known most famously for being a walking simulator, puts the game play right into the landscape by challenging players to navigate the terrain. This is quite unusual for games since most open world landscapes are designed to be easily traversed and creates challenges with other strategies such as having enemies or needing to find items. *Mountain* doesn't require active gameplay and offers the most conceptual redefinition of immersion through passive interaction. Observation and the passage of time is the gameplay.

My design conjecture is a slight reimagining of a project I created a year ago. It builds on the discussion of intertwining immersion, slowness, and infiniteness to visualize ecological timescales via what might be considered a productivity app. It is an app that I can imagine myself developing further as a project for thesis.

Let this be a conversation starter for immersion through and alongside environment centered media. This is curated to advocate for interactive media that centers mindful engagement with digital environments. In the future, I will explore these concepts in relation to a schedule of in-game events.

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What's wrong with virtual trees? Restoring from stress in a mediated environment

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Abstract

Restorative environments are environments that can help restore depleted attention resources or reduce emotional and psychophysiological stress. These effects have been demonstrated not only in real environments, but also in mediated (projected, broadcasted, etc.) environments. However, the importance of simulation qualities to restoration outcomes has not been systematically studied. The present experiment investigates the importance of immersion in a mediated environment in relation to restoration. Is a projected natural environment more restorative when one is more immersed in it, and hence feels more present in it? The hypothesis was that a more immersive projection would show stronger stress-reducing effects of a mediated restorative environment. After performing a stress-inducing task, participants watched a nature film on either a high or low immersive screen. Physiological measurements (heart period and skin conductance level) were taken throughout the experiment. In addition, we measured self-reported affect and presence using the ITC-Sense of Presence Questionnaire. Significant effects of the screen size manipulation appeared on physiological measures, but not on self-reported affect. The data showed an interaction between screen size and restorative phase on heart period and skin conductance level, indicating stronger restoration for the immersive screen condition over time. We therefore conclude that immersion enhances restorative potential of a mediated natural environment. Self-reported affect did correlate significantly with experienced presence, illustrating the relevance of this experiential counterpart of immersion, although a mediating effect of presence has not yet been established.

Keywords: Restorative environments; Environmental simulation; Immersion; Presence; Psychophysiology; Nature

1. Introduction

What's wrong with plastic trees? Although at first glance most of us would fiercely discard the idea of 'fake' nature, reality teaches us that our need for nature and natural elements often is in conflict with the type of setting we are in and that many of us then divert to 'fake' replacements. For instance at work, in hospitals or institutions where nature is not readily available, we in fact often do accept some kind of meagre surrogate or simulation of nature (potted plants, artificial plants, pictures of nature) when the real thing is not at hand. Reflecting on these issues, Wohlwill (1983, p. 19) at one time raised the question: 'what would it take to simulate a natural environment, one that would in fact be accepted as a satisfactory surrogate by us'. At the time, the term 'simulation' mostly referred to physical models, as for instance the famous Berkeley Simulation Laboratory project (Bosselmann & Craik, 1987). In our world of rapidly developing media, information and computer technology, physical models are gradually being replaced by computer simulations and other mediated environments, such as reproduced through film or slides. Krieger's (1973) provocative statement 'What's wrong with plastic trees?' is now likely to be rephrased into the question: 'What's wrong with *virtual* trees?'

The present study explores this question in the domain of restorative environments. To our knowledge, this manuscript is a first exploration of whether the quality of a simulation matters in restoration.

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1.1. Restoration

Restoration involves renewing diminished functional resources and capabilities (Hartig & Staats, 2003; Parsons & Hartig, 2000, Chapter 30). It enhances the ability to focus attention (Hartig, Mang, & Evans, 1991), reduces stress (Ulrich, 1983), and leads to positive affective states (Hartig, Nyberg, Nilsson, & Gärling, 1999). The number of publications reporting restorative effects of certain types of physical environments is growing. Two prominent theories coexist, one claiming recovery from psychophysiological stress as the central process (Ulrich, 1983), the other recovery from directed attention fatigue (Kaplan & Kaplan, 1989). In a recent article, Hartig, Evans, Jamner, Davis, & Gärling (2003) note that there is an emerging consensus that the processes described in both theories can run simultaneously and to some degree independently of one another, with different outcomes emerging at different times.

In his psychoevolutionary theory, Ulrich (1983) focuses mainly on the visual perception of certain environments, and the aesthetic and affective reactions associated with it. The visual properties influencing aesthetic preference and interest Ulrich discusses are: complexity, structure, depth, ground surface texture, threat or tension, deflected vistas, and water. According to Ulrich's evolutionary approach, surroundings with these properties optimally support approach and avoidance behaviours, which are relevant for people's well-being and survival. The experience of visually pleasant physical surroundings is thought to reduce stress by eliciting positive emotions, sustaining nonvigilant attention, restricting negative thoughts, and returning physiological arousal to more moderate levels (Parsons & Hartig, 2000, Chapter 30), see also (Ulrich et al., 1991).

Attention Restoration Theory (ART, Kaplan & Kaplan, 1989) postulates that directing or focusing attention requires a certain capacity that can become depleted, resulting in directed attention fatigue. This resource can slowly regenerate in the absence of an ongoing need for directed attention, but ART suggests that it will be restored faster by what Kaplan and Kaplan (1989) have called 'involuntary attention', and later 'fascination'. This refers to attention that is drawn by stimuli that are fascinating in themselves, not requiring the mental resources directed attention does. Fascination is drawn by stimuli that are reasonably complex, coherent, and legible and yet hold some mystery. Fascination, however, is one necessary, but not sufficient prerequisite for restoration. Ideally, the environment should also afford a feeling of 'being away', have 'extent' and be compatible with the viewer's wishes and capacities.

Although these two theories attribute the restorative effects to different processes, both support the idea that nature functions well as a restorative environment. These expectations have been supported by a number of empirical studies, reporting a stronger reduction of negative feelings such as anger and aggression and a stronger increase of overall positive affect such as happiness, friendliness, or elation after viewing natural vs. urban scenes (Hartig, Böök, Garvill, Olsson, & Gärling, 1996; Hartig et al., 1991, 2003; Hartig, Korpela, Evans, & Gärling, 1997). In addition, similar empirical evidence exists of physiological restoration in terms of skin conductance, muscle tension, pulse transit time and blood pressure (e.g. Hartig et al., 2003; Laumann, Gärling, & Stormark, 2003; Parsons, Tassinary, Ulrich, Hebl, & Grossman-Alexander, 1998; Ulrich et al., 1991). These beneficial effects of nature should clearly stimulate us to take better care of our natural environments, but for those in need of restoration who cannot directly access these places—hospitalized patients, people at work—media such as pictures, slides and films can be put to use and in the near future we can probably add virtual reality to that list. Although Levi and Kocher (1999) pointed out the dangers and pitfalls of virtual nature and virtual reality technology in terms of devaluation of local natural areas, we argue that this technology also holds great potential value for human health and well-being.

Only a small number of studies on restorative effects have actually taken participants on a visit to natural places, e.g. Hartig et al. (1991). Instead, most of these studies have been performed in psychological laboratories, employing photographs, slides, or videos, under the implicit assumption that being subjected to projected environments will result in similar effects as experiencing the real environment in its full sensorial richness—in other words assuming 'experiential isomorphism' (IJsselsteijn, 2004) for mediated and unmediated stimuli. The options for optimizing the media setting (immersion) or the experience of actually being there (presence) have not been systematically studied in the domain of restoration theory.

1.2. Realism, immersion and presence

In rethinking Wohlwill's question what would be a satisfactory surrogate of real nature, numerous aspects of mediated environments spring to mind that make it different from 'real nature', e.g. fewer senses are stimulated, interactivity with the environment is more restricted, and the resolution of the picture and rendering quality give lower pictorial realism, to name but a few. All of these aspects will make a mediated environment feel less 'real' and will affect our experience of actually being in that environment, i.e. 'presence'. Technical characteristics of a simulated or mediated environment that critically influence the user's perception have been investigated by environmental psychologists (e.g. Appleton & Lovett, 2003); Bosselmann, 1993; Bosselmann & Craik, 1987; Daniel & Meitner, 2001; Heft & Nasar, 2000; Marans & Stokols, 1993; Orland, 1993) and are currently at the centre of attention of researchers in the domain of presence and media psychology (for reviews see IJsselsteijn, 2004;

IJsselsteijn, de Ridder, & Freeman, 2001; Nash, Edwards, Thompson, & Barfield, 2000; Sadowski & Stanney, 2002).

Several researchers in environmental psychology have discussed and studied the validity of simulations. Most studies have been performed in fields of environmental aesthetics and landscape assessment and preference. For instance, based on an extensive review on the utility of simulations for aesthetic judgements, Stamps (1990) concluded that photographs can be considered valid representations. Reviews by Shuttleworth (1980), Zube, Simcox, and Law (1987), and Bosselmann and Craik (1987), led to similar conclusions. However, others state a number of concerns regarding the validity of photographs as representations for landscape assessments, e.g. Hull and Stewart (1992) point out threats to the ecological validity by differences between on-site and off-site contexts as well as a concern regarding the appropriate unit of analysis for validity tests. In a multiple sorting task employing only photographs, Scott and Canter (1997) subsequently found marked differences between results based on the content of photographs versus the places represented in them.

Kroh and Gimblett (1992) demonstrated that for certain environments, multi-sensory input and dynamic characteristics cause differences between the experience and assessment of real environments and their simulations. In addition to this finding, Heft and Nasar (2000) showed differences between static and dynamic displays. Interesting in this respect is also the work reported by Huang, Parsons, and Tassinary (2004), discussing video representation to capture sound and motion, but suggesting that in addition to these characteristics, continuous multi-views might reflect human interaction with the environment, thus also contributing to ecological validity.

Recent work investigating the validity of computer-based simulations in landscape assessment, points out that pictorial (or photo-) realism can play a pivotal role in aesthetic assessment tasks that require the person to evaluate fine details of the environment, colour schemes et cetera. For instance, Appleton and Lovett (2003) found that viewers judged representations as more accurate and valid as their level of detail increased. In addition, Daniel and Meitner (2001) reported very low correlations between beauty judgements of the same scenes with different levels of visual realism.

From all this we can conclude that the validity of simulations in environmental psychology research is still far from established and depends both on the representation (e.g. pictorial realism, multi-modality, static vs. dynamic, possibilities for interaction), environmental content (e.g. presence of dynamic characteristics), and the task (e.g. aesthetic judgement vs. place experience, explicit instructions to assess place vs. picture).

In research on the experience of virtual environments, two concepts have been introduced that may also prove useful for environmental psychology: immersion and presence. *Immersion* describes physical properties of the media technology. For instance, Slater and Wilbur (1997) define immersion as the 'extent to which computer displays are capable of delivering an inclusive, extensive, surrounding and vivid illusion of reality' (p. 604) to the participant's senses. In other words, immersion is the extent to which a display system blocks out sensory input from the outside world, immerses the user in the displayed world, in terms of the number of senses that are addressed and the richness and completeness of their stimulation, and enables interaction with this world. *Presence* on the other hand describes the individual's experience, her feeling of 'being there' in the mediated environment. IJsselsteijn (2004) states: 'Presence can be conceptualized as the experiential counterpart of immersion—the human response' (p. 136). This experience becomes stronger as the media technology becomes more immersive and perceptually realistic. Examples of media technology characteristics, i.e. immersive properties, that have been reported to influence experienced presence are the number of modalities that are stimulated, pictorial realism, screen size, and interactivity (for reviews see IJsselsteijn, 2004; Nash et al., 2000; Sadowski & Stanney, 2002; Schuemie, van der Straaten, Krijn, & van der Mast, 2001).

The rationale for investigating presence and immersion in the context of restorative environments is twofold. First, considering the definition of presence as the experience of 'being there' in a mediated environment (IJsselsteijn, 2004), it becomes a variable of interest that may moderate (or perhaps even mediate) the restorative effectiveness of mediated nature. In fact, as noted previously, the majority of studies investigating restorative environments make use of media of some sort in order to present the environments under study. In related studies such as for instance, when used for therapeutic purposes, the response similarity of virtual environments to real environments is considered a prerequisite (e.g. de Kort, IJsselsteijn, Kooijman, & Schuurmans, 2003; Meehan, Insko, Whitton, & Brooks, 2001; Meehan, Razzaque, Whitton, & Brooks, 2003). Studies in the domain of therapeutic virtual environments for desensitization in phobia treatment have reported that a greater sense of presence, i.e. *experiential realism*, produces stronger fear reactions and higher treatment efficacy (e.g. Hoffman, Garcia-Palacios, Carlin, Furness, & Botella-Arbona, 2003; Regenbrecht, Schubert, & Friedmann, 1998; Wiederhold, Davis, & Wiederhold, 1998; see also Schuemie et al., 2001 for a review).

Strikingly, enhancements in *pictorial realism*—as reported crucial for aesthetic assessments of buildings and landscapes—have smaller effects on users' experience and responses than for instance interactivity of a simulation or tactile augmentation. Some studies even report that low-fidelity, cartoon-like virtual environments have been found to elicit fear responses in phobic patients (North, North, & Coble, 2002, Chapter 51). Thus, in contrast to the domain of aesthetics where pictorial realism is essential, the efficacy of virtual environment therapy depends crucially on the broader concept of experiential realism (Herbelin, Vexo, & Thalmann, 2002), as is the case for the presence experience in general (e.g. Snow & Williges, 1998; Welch, Blackmon, Liu, Mellers, & Stark, 1996).

Secondly, at the level of psychological theory, we note that there are a number of interesting links between the theorized dimensional structure of presence and the dimensions of restoration, suggesting potentially useful connections between the two constructs. As was reported earlier, components of restoration that have been described in literature include 'being away', 'fascination', 'extent', and 'compatibility' (Kaplan & Kaplan, 1989). Regarding presence, a number of independent studies have arrived at a similar factor structure that appears to underlie presence (Freeman, 2004; Lessiter, Freeman, Keogh, & Davidoff, 2000; Schubert, Friedman, & Regenbrecht, 2001). These factors can roughly be characterized as 'physical space', 'naturalness' and 'engagement'. 'Physical space' refers to the sense of being located in a continuous spatial environment and is mainly related to the media form. Conceptually, it appears closely related to 'being away' as one of the critical elements of restoration, provided the physical space one feels present in takes one away from the stressful environment one needs to restore from. Moreover, it is related to 'extent' as the perception of a continuous physical space will be suggestive of a larger environment to explore beyond the immediate boundaries of the media frame. 'Naturalness' refers to whether the presented content is believable and realistic and is, as such, a product of both media form factors and the represented content. Although there is no straightforward mapping onto elements of restoration, it appears that naturalness may be related to both extent and compatibility—in particular as in the latter case the role of expectation is crucial, which is also the case for perceived realism. Engagement, finally, refers to the interest in the mediated environment, and is thus mainly related to the presented content and the individual's attention or absorption in relation to that particular content. The engagement dimension appears closely related to the fascination that appears to be a requirement in the attention-based accounts of restoration (Kaplan & Kaplan, 1989).

1.3. Real nature?

The question whether simulations are satisfactory for restoration purposes has hardly been addressed, although most of the studies performed in this domain make use of simulations of environments instead of actual ones. Indeed, requirements of photorealism are generally met as reproductions of nature such as slides and film are used—we know of no restoration studies employing rendered virtual environments—and restorative effects are found. But only little or no attention is paid to explicitly testing the influence of display characteristics or the experience of actually being there in a real environment, through means such as screen size, interactivity, or multimodal displays. As yet we do not know whether the quality of, and the level of immersion in the representation contribute to the restorative effects generated by the environment that is depicted. We think the experience of nature and its restorative powers differs significantly from pure aesthetic assessments, and hence feel that one cannot simply adopt the conclusions regarding the importance and sufficiency of pictorial realism. It is very well possible that adding stimuli via other modalities, or using more immersive displays also contributes to the experience of actually being in nature. Therefore, it would be very dangerous to simply assume that any photorealistic representation will do, or that each representation will be as effective as the next.

In parallel to the use of mediated or simulated environments in therapeutic contexts, we expect that treatment in a restorative environment will be more successful as the setting better enables a person to experience presence in it. In investigating this, one should look beyond pictorial realism, and consider experiential realism and immersion in a broader sense (see also: de Kort & IJsselsteijn, 2006). Examples of this are, for instance, adding the auditory modality in photorealistic natural environments (Nordahl, 2006), or adding motion parallax (a depth cue) to increase the experienced level of realism for an artificial window as Radikovic, Leggett, Keyser, and Ulrich (2005) have reported employing image based rendering, or as IJsselsteijn, Oosting, Vogels, de Kort, and van Loenen (2006) report, employing convincing, yet less computationally demanding techniques. In the present study, we chose a screen size manipulation to investigate the effects of a more immersive display of nature on restoration. This type of manipulation has been successfully used in earlier research to influence the experience of presence (e.g. Hendrix & Barfield, 1996; IJsselsteijn, de Ridder, Freeman, Avons, & Bouwhuis, 2001).

An experiment was set up to test whether immersion matters in restoration. We have chosen to manipulate the level of immersion into nature scenes to investigate the effects of characteristics of the representation on restorative effects. Restorative stimuli were identical for both experimental groups, as immersion was manipulated through screen size. Both self-report measures of affect and psychophysiological measures were taken to investigate effects of immersion, and possible mediating effects of presence, on restoration. We hypothesized that as the mediated environment was presented in a more immersive way, engendering a stronger presence experience, restorative effects would be stronger.

2. Method

2.1. Design

The effect of immersion in a nature simulation on restoration was studied in an experiment in which after a stressful episode, participants watched a film of a restorative environment under low or high immersion conditions. Immersion was manipulated between-subjects by varying screen size. In the low immersion condition the film of the restorative environment was shown on a small screen, whereas in the high immersion condition it was shown on a large screen. To assess whether the restorative effect of the nature film depended on the level of immersion, we measured changes in participants' skin conductance level (SCL), inter beat interval (IBI), and self-reported positive and negative affect. Presence was explored as a mediating variable.

2.2. Participants

A student sample of $N = 80$ participated in the experiment, of which 36% was female and 64% was male. Their mean age was 24 (S.D. = 4.8). The participants were paid € 8 in exchange for their time. Participants were randomly assigned to the two immersion conditions.

2.3. Setting

The experiment was conducted at the Eindhoven University of Technology, in a laboratory. Participants were seated at a table in front of a large back projection screen. The back projection screen of 110×145 cm (72″) was positioned with its centre on eye level, at a 2.25 m distance approximately. On the table was a computer on which participants received instructions, performed the stress task, and filled in the self-report measures. Apparatus for taking physiological recordings were placed behind the table and are described in Section 2.8. The light was dimmed and there were no noises audible from outside the laboratory room.

2.4. Stressor task

In this experiment we made use of the Markus & Peters Arithmetic Test (MPATest, Peters et al., 1998) to increase participants' level of stress prior to exposing them to the film of the restorative environment. This stressor consists of a mental arithmetic task in combination with uncontrollable industrial noise. The effectiveness of the stressor has been confirmed by previous research, showing that the stressor brings about heightened heart rate (Peters et al., 1998), increased skin conductance and a negative mood (Markus et al., 1998, 2000). The stressor task took between 18 and 32 min. The variation in duration was due to the time participants took to read the instructions, and to perform the first exercises of the task, as the task only continued after three correct answers. The actual stressor task took about 16 min, consisting of sixteen 1-min trials. All questions were two-step calculations, presented on subsequent screens, typically consisting of a product and a sum with numbers of up to 4 digits.

2.5. Nature film

In the two immersion conditions the same film was presented. The film was a compilation of nature scenes, without sound, from two DVD's created under the authority of "Vereniging Natuurmonumenten", a Dutch nature reserve association. It consisted of numerous pieces of film, some of them panning slowly across the landscape, others static, focusing on for instance waving sheer or nonthreatening animals (e.g. sheep, birds), and a few close-ups of plants or flowers. The landscape was semi-open, contained both open areas, bushes and shrubs, as well as trees, and water. The duration of the nature film was exactly 10 min.

2.6. Immersion manipulation

Immersion was manipulated by varying screen size, because this manipulation does not change the content of the sensory input and has been shown to influence the experience of presence (e.g. Hendrix, & Barfield, 1996; IJsselsteijn, de Ridder, Freeman, Avons, et al., 2001). In the low immersion condition the nature film covered 47×60 centimetres (31″) of a 110×145 cm (72″) screen. In the high immersion condition the film covered the entire screen. This is equivalent to a 35° visual angle/field of view (FOV) in high immersion, and a 15° FOV in low immersion.

2.7. Presence measure

The subjective state of presence was measured using the ITC-Sense Of Presence Inventory (ITC-SOPI, Lessiter et al., 2000). This inventory taps four different factors (spatial presence, engagement, ecological validity/naturalness, and negative effects) with 44 items in total. Some exemplary items are: 'the displayed environment seemed natural', 'I had a sense of being in the scenes displayed', and 'I felt I was visiting the places in the displayed environment'. The items are statements and participants are asked to indicate their level of agreement with these statements on scales ranging from 1 "Strongly disagree" to 5 "Strongly agree". The reliability of the subscales was satisfactory, as indicated by Cronbach's α scores between 0.60 and 0.92.

The questionnaire was administered immediately after the film.

2.8. Psychophysiological measures

Psychophysiological data were acquired and analysed using a BIOPAC MP100 workstation and AcqKnowledge® software. Skin conductance level (SCL) was recorded directly using the constant voltage technique. A BIOPAC Electrodermal Activity Amplifier Module (GRS100B) measured the absolute skin conductance for every 5 ms (200 samples/s). The lowpass filter was set to 1 Hz; the gain was set to 20 μ℧/V. Conductance was measured from the nondominant hand by placing BIOPAC Electrodermal Activity transducer (TSD103A) Ag–AgCl electrodes on the first phalange of the index and middle fingers. A nonirritating electrode gel (Parker Signa gel) was used as the electrolyte.

Heart period (inter beat interval, IBI) was derived from an electrocardiogram (EKG), which was recorded from two BIOPAC Ag–AgCl disposable shielded electrodes (10 mm contact area) placed on each wrist after preparing the skin with alcohol. Another unshielded electrode was placed on an ankle for the ground. To obtain heart rate, the EKG signal was amplified with a BIOPAC Electrocardiogram Amplifier module (ECG100B). The gain was set to 500 (40 mV), the high pass filter switched to 0.05 Hz, the sample rate was 200 samples per second. The module has an *R*-wave detector[1] function (i.e. the big positive peak in the raw EKG signal), which produces a smoothed positive peak every time the *R*-wave is detected, useful for rate calculations.

The physiological measures were taken during a baseline period (6th–9th min), during the stress episode (1st–5th, 6th–10th, 11th–15th min), and during the restoration episode (2nd–4th, 5th–7th, and 8th–10th min).

2.9. Affect measures

In studies of the structure of affect, positive and negative affect have consistently emerged as two dominant and relatively independent dimensions (e.g. Lane et al., 1997; Watson, Clark, & Tellegen, 1988). In the absence of a validated Dutch short-term emotion scale, an affect questionnaire was therefore developed to measure positive and negative affect. The entire questionnaire consisted of 16 affect words, selected after inspecting English versions of two validated and often used scales, The Positive and Negative Affect Schedule (PANAS, Watson et al., 1988) and the Zuckerman Inventory of Personal Reactions (ZIPERS, Zuckerman, 1977). These affect words appeared in random order on the computer screen, embedded in the sentence: "I feel …", followed by a 7-point answering scale, ranging from 0 "Not" to 6 "Very much". Examples of positive affect words are "relaxed" and "cheerful". Examples of negative affect words are "tense" and "irritated". Participants completed the affect questionnaire three times during the experiment: prior to the stressor, after the stressor, and after the nature film.

The mean score on the eight positive items was used as a measure of positive affect (α ranged between 0.73 and 0.84 for the three measurements) and the mean score on the eight negative items was used as a measure of negative affect (Cronbach's α ranged between 0.69 and 0.78). Correlations between positive and negative affect were low to moderate (pre-stressor: -0.08, ns; post-stressor -0.46, $p<0.001$; post-film -0.27, $p=0.04$).

[1]The '*R*' wave detector circuitry consists of a 17 Hz band pass filter (the setting determining the width of the Band pass filter $Q=5$; The filter has a bandwidth F_0/Q). This is followed by a full-wave rectifier, followed by a 10 Hz three pole, low-pass filter (MP100 Hardware Guide, p.66; MP100 System Guide, p. 62).

2.10. Procedure

Upon arrival in the laboratory, participants were told that the experiment involved physiological measurements and were asked for their informed consent. The experiment was performed individually. After the electrodes were attached, the participant was asked to relax for 10 min, while baseline recordings were taken. Participants then started the experiment by following the instructions on the computer screen. Subsequently, they filled out and performed the pre-stressor affect questionnaire, the stressor task and the post-stressor affect questionnaire; they then watched the nature film and again filled out the affect questionnaire and the ITC-SOPI. Participants were then debriefed and dismissed. The experiment lasted approximately 1 h.

3. Results

Below the results of the experiment are presented. In Section 3.1, the effects of the stressor task on physiological and self-report measures are tested, to make sure the test did indeed induce stress and that both experimental groups were equal before the experimental manipulation. Repeated measures analyses of variance (REMANOVA) were used to test these effects. Research hypotheses are tested in Section 3.2. Again, REMANOVAs are used to compare treatment effects over time. Based on the hypothesis that people will restore quicker in highly immersive nature presentations, we expected to see significant interaction effects between Phase (i.e. time) and Immersion (i.e. the presentation condition), representing steeper trends for the high immersion condition than for the low immersion condition. In Section 3.3 the effects of the immersion manipulation on self-reported experience of presence are tested, and correlations between presence components and indicators of psychophysiological and emotional restoration are explored. All analyses were performed using SPSS.

3.1. Effectiveness of stress task

To test whether the stress task was effective in eliciting stress, we conducted a 2×2 mixed-model repeated measures analysis of variance (REMANOVA) with skin conductance level (SCL) as the dependent variable, Immersion as a between Ss variable and Phase (baseline vs. end of the stressor-period) as the within Ss variable. This analysis showed a significant effect of Phase, $F(1,78)=108.84$, $p<0.001$. The stress task increased skin conductance level (baseline $M=10.57\,\mu\mho$, S.D. $=6.06$, stressor $M=14.92\,\mu\mho$, S.D. $=8.25$). Neither the main effect of Immersion nor the Phase $\times$ Immersion interaction effect were significant, $F<1$, ns. This implies that there were no significant differences in SCL before treatment.

A similar analysis was performed with inter beat interval (IBI) measured during baseline and during the stressor. Again, the effect of Phase was highly significant,

$F(1, 78) = 19.56$, $p < 0.001$. In accordance with expectations, the stress task decreased inter beat interval (baseline $M = 0.85$ s, S.D. $= 0.13$, stressor $M = 0.81$ s, S.D. $= 0.10$). Both the main effect of Immersion, $F(1, 78) = 1.7$, $p = 0.19$, and the interaction effect Phase × Immersion, $F < 1$, ns, were insignificant. This shows that there were no significant differences in IBI before treatment.

We also tested the effect of the stress task on negative affect. A REMANOVA with negative affect as the dependent variable and Immersion and Phase (before vs. directly after the stress task) as the independent variables showed a significant effect of Phase, $F(1, 78) = 229.38$, $p < 0.001$. Negative affect increased due to the stress task (before stressor $M = 2.00$, S.D. $= 0.62$, after stressor $M = 3.44$, S.D. $= 0.84$). Both the main effect of Immersion and the interaction effect Phase × Immersion were insignificant, $F < 1$, ns. This demonstrates that there were no significant differences in negative affect before treatment.

A REMANOVA with positive affect as the dependent variable and Immersion and Phase (before and directly after the stress task) as the independent variables also showed a significant effect of Phase, $F(1, 78) = 196.74$, $p < 0.001$. The stress task resulted in a decrease of positive affect (before stressor $M = 4.05$, S.D. $= 0.61$, after stressor $M = 2.62$, S.D. $= 1.02$). Both the main effect of Immersion and the interaction effect Phase × Immersion were insignificant, $F < 1$, ns. This implies that there were no significant differences in positive affect before treatment.

Hence all stress indicators point in the same direction, that the stressor task was successful in eliciting stress. In addition, there were no significant differences between conditions before treatment.

3.2. Effect of immersion on restorative impact

3.2.1. Physiological measures

To test the hypothesis that immersion influences the restorative impact of the nature film, a mixed-model repeated measures analysis of variance (REMANOVA) was performed with skin conductance level (SCL) as the dependent variable, Immersion as the between Ss variable and Phase (2nd–4th min, 5th–7th min, and 8th–10th min of the restorative period) as the within Ss variable. A marginally significant effect of Phase was found, $F(1.84, 143.1) = 2.80$, $p = 0.07$, as well as a marginally significant interaction-effect of Phase × Immersion, $F(1.84, 143.1) = 2.95$, $p = 0.06$[2,3,4]. There was no significant main effect of Immersion, $F(1, 78) = 1.26$, $p = 0.27$. As can be seen in Fig. 1, skin conductance level decreased in the large screen condition, but did not do so in the small screen condition. Means are reported in Table 1.

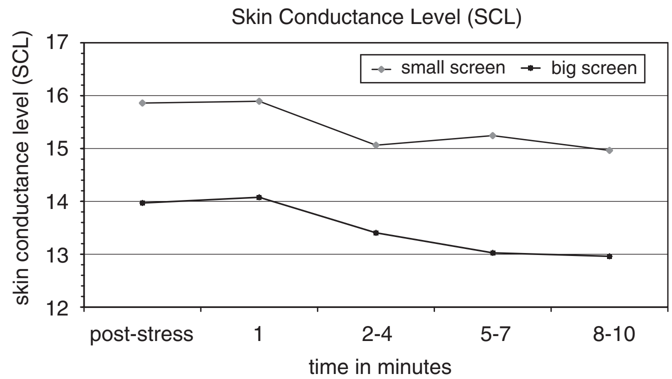

Fig. 1. Skin conductance level (SCL) during nature film.

A similar analysis was conducted with inter beat interval as the dependent variable. This analysis showed a significant main effect of Phase, $F(1.76, 137.2) = 8.46$, $p < 0.001$, but the interaction-effect with Immersion failed to reach significance, $F < 1$, ns. This indicates that inter beat interval did not develop differently for the two experimental conditions. Again, there was no main effect of Immersion, $F(1, 78) = 1.59$, $p = 0.21$. Results are shown in Fig. 2. Means are reported in Table 1.

Both Fig. 1 and 2 seem to show a difference between experimental groups from the first phase (covering the 2nd–4th min) onwards. Therefore, additional analyses were performed, exploring the development of SCL and IBI in the 1st min of the nature film. Again a REMANOVA[5] was performed with skin conductance level (SCL) as the dependent variable and Immersion and Phase (1st vs. 2nd vs. 3rd vs. 4th min of the restorative period) as the independent variables. A significant effect of Phase was found, $F(1.50, 117.2) = 20.36$, $p < 0.001$, but no significant interaction-effect with Immersion, $F < 1$. As can be seen in Fig. 3, the decrease in skin conductance level in the first 4 min did not develop differently in the two experimental conditions. There was no significant main effect of Immersion, $F < 1$, ns.

A similar analysis was conducted with inter beat interval as the dependent variable. This analysis showed a significant main effect of Phase, $F(3, 234) = 14.34$, $p < 0.001$, as well as an interaction-effect with Immersion, $F(3, 234) = 8.70$, $p < 0.001$. Fig. 4 shows that IBI recovered in the 1st min for the large screen group, but not for the small screen group. There was no main effect of Immersion, $F(1, 78) = 1.07$, $p = 0.30$.

3.2.2. Self-reported affect

The effects of the nature film and the immersion manipulation on negative and positive affect were again

[2] Greenhouse–Geisser corrections are reported as the sphericity assumption was violated.

[3] The multivariate test showed a significant effect of the Phase × Screen size interaction: $F(2, 77) = 2.14$, $p = 0.03$.

[4] In a repeated measures ANCOVA, similar to the REMANOVA reported here, but with the skin conductance level during the last stressor phase as a covariate, the main effect of Phase disappeared, but the Phase × Immersion interaction effect remained the same.

[5] In a repeated measures ANCOVA, similar to the REMANOVA reported here, but with inter beat interval during the last stressor phase as a covariate, the main effect of Phase became somewhat smaller, but the Phase × Immersion interaction effect remained the same (NS).

Table 1
Means and SD's of psychophysiological measures, subjective affect and experienced presence for both experimental conditions

	Small screen		Big screen	
	M	S.D.	*M*	S.D.
Skin conductance level (SCL)				
Baseline	11.18	7.32	9.97	4.49
Post-stressor	15.86	10.26	13.97	5.55
Restoration phase1	15.06	9.62	13.40	5.46
Restoration phase 2	15.24	9.90	13.03	5.26
Restoration phase 3	14.96	9.65	12.96	5.33
Inter beat interval (IBI)				
Baseline	0.832	0.120	0.871	0.134
Post-stressor	0.802	0.099	0.827	0.103
Restoration phase 1	0.890	0.121	0.928	0.118
Restoration phase 2	0.890	0.117	0.921	0.120
Restoration phase 3	0.881	0.116	0.910	0.107
Positive affect self-report				
Baseline	3.98	0.66	4.11	0.54
Post-stressor	2.55	1.12	2.69	0.92
Post-restoration	3.68	0.65	3.87	0.74
Negative affect self-report				
Baseline	1.89	0.68	1.78	0.68
Post-stressor	3.57	1.02	3.51	0.94
Post-restoration	2.22	0.80	1.96	0.81
Presence experience self-report				
Spatial presence	1.81	0.53	1.95	0.63
Engagement	2.56	0.60	2.77	0.63
Naturalness	3.41	0.78	3.57	0.51
Negative effects	2.17	0.59	1.88	0.51

Note: Skin conductance level (SCL) measured in mumho; Inter beat interval (IBI) measured in seconds; affect scores vary from 0 to 6; presence scores vary from 1 to 5.

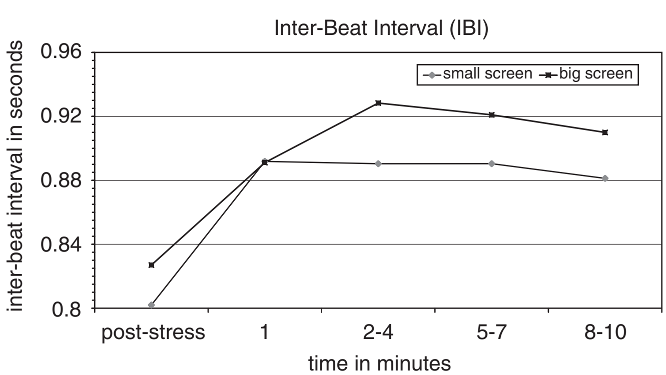

Fig. 2. Inter beat interval (IBI) during nature film.

tested with repeated measures ANOVAs. The REMANOVA with negative affect as the dependent variable and Immersion and Phase (before vs. directly after the nature film) as the independent variables showed a significant effect of Phase, $F(1,78) = 225.01$, $p<0.001$. Negative affect decreased due to the nature film (see Table 1). Both the main effect of Immersion and the interaction effect Phase $\times$ Immersion were nonsignificant, $F<1$, ns.

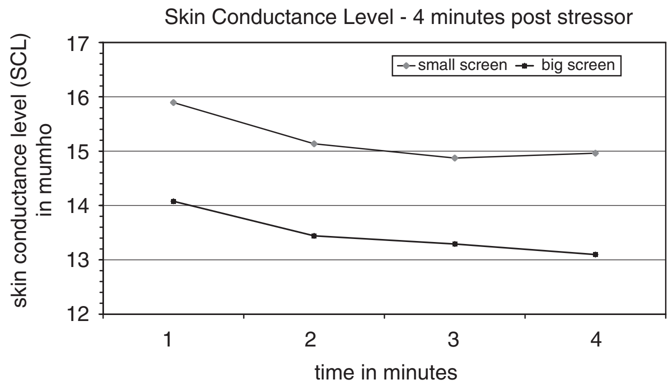

Fig. 3. Skin conductance level (SCL) during the 1st min of the nature film.

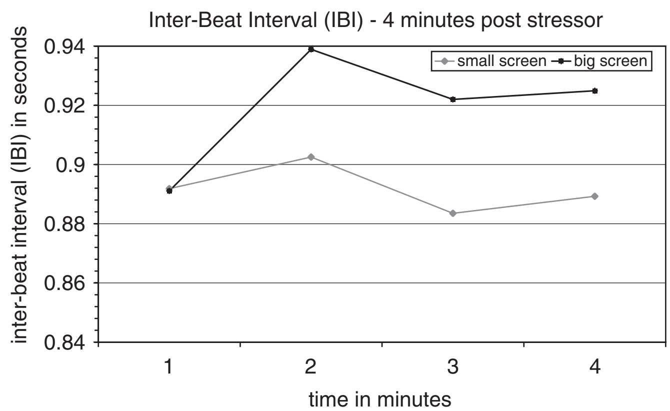

Fig. 4. Inter beat interval (IBI) during the 1st min of the nature film.

A REMANOVA with positive affect as the dependent variable and Immersion and Phase as the independent variables also showed a significant effect of Phase, $F(1,78) = 133.27$, $p<0.001$. The nature film resulted in an increase of positive affect for both experimental groups. Both the main effect of Immersion and the interaction effect Phase $\times$ Immersion were nonsignificant, $F<1$, ns. This implies that there were no significant differences between the small and large screen conditions. Results for positive and negative affect are shown in Fig. 5. Means are reported in Table 1.

3.3. Effects of immersion on experienced presence

To examine whether the immersion manipulation had an impact on experienced presence, a multivariate analysis of variance was conducted with the four experienced presence factors (spatial presence, engagement, ecological validity/naturalness, and negative effects) as the dependent variables and Immersion as the independent between Ss variable. Results are reported in Table 1. This analysis showed no significant result, $F(4,75) = 1.59$, $p = 0.19$. Hence screen size seems to have failed to influence experienced presence significantly, although all components showed trends in the expected direction. It should be

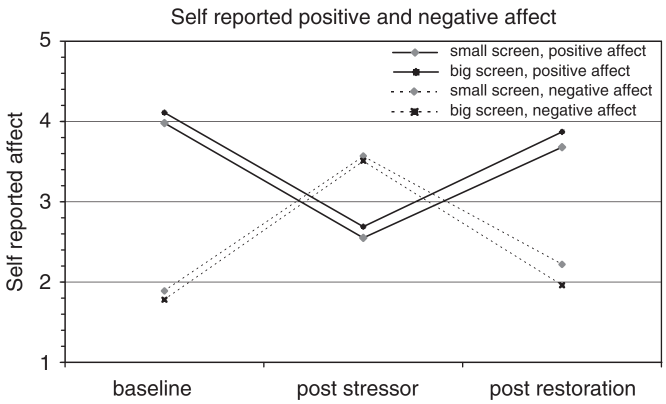

Fig. 5. Positive and negative affect scores following the stressor and following the nature film, for both experimental conditions.

noted that levels of experienced presence were low in both conditions, perhaps indicating a threshold problem of the measurement. Spatial presence was rated $M = 1.81$ (S.D. $= 0.53$) in the small screen condition and $M = 1.95$ (S.D. $= 0.63$) in the large screen condition. No subsequent mediation analysis was performed.

Bivariate correlations between the presence components and restoration indicators were explored. No significant correlations emerged between indicators of presence and skin conductance level or inter-beat interval. The data did show significant relationships between all three presence components and indicators of self-reported affect after the nature film. All correlations were in the expected direction, indicating more positive affect for higher levels of experienced presence, and lower levels of negative affect. Reported spatial presence was correlated to both positive ($r = 0.26$, $p = 0.02$) and negative affect ($r = -0.25$, $p = 0.03$). Correlation with the engagement component were even stronger, with both positive ($r = 0.49$, $p < 0.001$) and negative affect ($r = -0.37$, $p = 0.001$). Naturalness was correlated significantly to positive affect ($r = 0.29$, $p = 0.01$), but only marginally to negative affect ($r = -0.21$, $p = 0.06$). Logically, correlations of presence components with self-report affect before and after the stressor (i.e. before the nature film) were nonsignificant, with the exception of the correlation between naturalness and positive affect before stressor ($r = 0.31$, $p = 0.01$).

4. Discussion

The present study was aimed at investigating the influence of immersion (manipulated through screen size) on the restorative potential of nature presented to the user via media technology. Some results were conclusive, however, some were not. Results on physiological measures were largely in correspondence with our expectations, findings on subjective variables, on the other hand, did not show the expected effects.

Both physiological measurements showed results confirming our hypothesis that immersion enhances restorative effects of a mediated natural environment. For skin conductance level, the immersion manipulation showed a marginally significant interaction with phase (over the 10 min restorative period). The results indicated that arousal—as indicated by SCL—followed a downward slope for the big screen condition and did not do so in the small screen condition. The differential effect was most pronounced in the 5–7th min. Similar results proved significant on the heart period (IBI) data. The interaction effect between immersion and phase (this time over the 1st min of the restorative period) was significant, again indicating faster recovery of inter-beat interval in the big screen condition. Differences between the immersion conditions disappeared over the full 10-min period of the nature film. Looking at the trajectories we are tempted to conclude that reductions of heart rate to baseline level had already been realized in the first phase of the nature film in both experimental conditions. Judging from the average increase in heart rate (or decrease in heart period) during the stressor we expect that the stressor task, although it did show effects on all measures in the expected direction, was not strong enough to require a lengthy restoration period for IBI data.

Results of affect measures also show complete restoration and return to baseline level after 10 min for both experimental conditions. Therefore, no significant differences in recovery of affect appeared between the two immersion conditions. We suspect that a more stressful task—requiring more and longer restoration might have shown differences between the two immersion conditions. It is, however, rather hard to induce these levels of stress in experimental research. Higher levels of induced experimental stress would certainly increase the potential to study effects of restorative conditions. For future studies we would also recommend the use of scales that more explicitly cover all quadrants of the affect circumplex (e.g. Russell, 1980), i.e. stretch up both the entire valence and arousal scale. In the self-report emotion scale of the present study, the valence dimension was adequately covered, but the arousal dimension may not have been. It is also somewhat unfortunate that we were not able to include measures of attention restoration in our experiment, due to time and timing restrictions in the procedure (only limited time is available for tapping subjective responses between and after experimental phases). Attention restoring processes are more time intensive than psychophysiological stress recovery (Hartig et al., 2003), so these effects could have rendered more insight in differential effects of both experimental conditions.

Unfortunately, the manipulation of screen size was not successful in producing a significant difference on our manipulation check of experienced presence, although all components of presence showed trends in the expected direction. This was striking, since the manipulation was considerable and screen size manipulations have been shown to influence presence significantly in earlier studies (e.g. Grabe, Lombard, Reich, Bracken, & Ditton, 1999; Hendrix & Barfield, 1996; IJsselsteijn, de Ridder, Freeman, Avons, et al., 2001; Prothero & Hoffman, 1995). We hypothesize two explanations for this finding. One possibility is that, as was indicated by the relatively low presence scores in both screen size conditions, we encountered a threshold problem of the measurement scale. A number of the items in the ITC-SOPI scale are clearly more relevant for interactive media. Although the authors claim that their scale is usable across media, its use in noninteractive settings is disputable given items such as ‘I felt I could interact with the displayed environment’, ‘I felt that the characters and/or objects could almost touch me’, ‘I felt that I could move objects’. A second possibility however is somewhat harder to tackle. Upon looking into earlier studies of screen size manipulations affecting presence, one notices that most research has employed within-subjects designs in testing this effect. Although Ijsselsteijn, IJsselsteijn, de Ridder, Freeman, Avons, et al. (2001) were able to demonstrate significant effects, most other researchers employing a between-subjects design similar to ours report the same difficulty in demonstrating significant effects on presence measures (e.g. Dillon, Keogh, & Freeman, 2002; Kim & Biocca, 1997). In such between-subjects experiments, participants cannot make direct comparisons between screen size conditions in the same sitting. Presence is a relatively new concept which bears particular relevance to immersive media experiences elicited by advanced media such as VR. Most nonexpert participants, lacking prior experience with immersive media to compare, may find it difficult to anchor the media experience in absolute terms (as is required in a between-subjects design), and may only be able to do so in comparative terms (as is effectively the case in a within-subjects design). Thus, self-report measures are likely to be less sensitive to differences in presence when used in a between-subjects design. This is a general concern in the field as reflected in the impressive number of recent efforts made in developing presence measurement instruments (e.g. van Baren & IJsselsteijn, 2004). Both explanations leave open the possibility that indeed the experience of presence mediates the relationship between immersion and restorative effectiveness, although the measurement of presence failed to differentiate between the two immersive conditions.

Significant correlations between components of presence and self-reports of positive and negative affect do suggest that there are interesting connections between these two concepts. Part of this relationship can be attributed to what one could call ‘media-content’ factors of the presentation, i.e. the nature scenes presented. In line with the theoretical resemblance between engagement and fascination, that was alluded to earlier in this text, correlations between subjective affect and presence component ‘engagement’ might be explained via the restorative process of ‘fascination’. Correlations between affect and presence components ‘physical presence’ and ‘naturalness’, which are typically considered ‘media form’ factors, appear to be related to ‘being away’ and ‘extent’ as was also touched upon in the introduction. Results on this issue are however inconclusive and call for more research.

We conclude that we have been able to show that immersion, manipulated via screen size, enhances restorative potential of a mediated natural environment, although we have not yet succeeded in showing the mediating effect of ‘experiential realism’ or ‘presence’ in this process. While media content factors have received the lion’s share of attention in restoration research, we advocate more research into the role of media form factors in optimizing restorative potential of nature. In scientific research, immersion and presence might become important means—perhaps even the key—to valid and effective use of mediated or simulated environments for psychophysiological and attention restoration. Presence could thus offer a generic metric to assess the psychological impact of the media representation chosen, thereby further enabling the controlled manipulation of media form factors (e.g. screen size) and their potential interactions with the presented content. Future research in this direction, employing other, perhaps more powerful manipulations of immersion than screen size should shed more light on this subject. Also, the use of a similar manipulation on urban scenes could be considered.

4.1. *Implications for restoration practice and research*

Hassles and troubles of everyday life make us feel stressed and mentally fatigued. In order to reduce the unhealthy consequences of stress, it is important to improve our mental, affective, and physical state. In the recent past there have been numerous studies indicating the beneficial effects of restorative—often natural—environments. These are said to help people reduce psychophysiological stress and renew attention and other psychological resources (Parsons & Hartig, 2000, Chapter 30). Unfortunately, restorative environments are not always at hand. An alternative would be to restore in a simulated (e.g. virtual) or mediated environment (e.g. slides and film). In fact, earlier studies in this domain have already demonstrated the restorative potential of nature films and slides. However, we would argue that these effects could be increased through intelligent and educated use of media technology. If a relatively moderate and simple screen size manipulation is effective, a more immersive environment, i.e. extensive, multimodal or interactive, should definitely have potential, for instance for therapeutic use.

Fully immersive mediated nature would be hard to realize with reproductions of environments, but computer simulations do offer possibilities for more full-blown experiences. Incorporating these types of environments in future research would not only teach us about media experience, but could also prove very useful for restoration research in general. As we become capable of carefully and independently manipulating the various stimuli and stimulated senses using virtual environment technology, there is great potential for studying and better understanding how environments ‘get under the skin’ and unravelling the mysteries that still exist in restoration theory. Now in using computer simulations for this type of research, given the present levels of VRT we would have to accept lower levels of pictorial realism than presently used in film and slides. This brings us back to the conflicting findings regarding the importance of pictorial realism in aesthetics and therapeutic use of VR as were discussed in the introduction. Before VRT can successfully be used in environmental psychology research and restoration practice, these issues call for more research efforts regarding the question: 'What's wrong with virtual trees?'

In the present study we did not venture into virtual environments, but stayed close to the type of materials generally used in restoration research. We conclude that we have been able to show that immersion enhances restorative potential of a mediated natural environment. The potential of more convincing presentations of 'real nature', e.g. such as is suggested in IJsselsteijn et al. (2006), employing relatively simple computation and tracking devices to create the illusion of depth in a pre-recorded or even real-time film presented via a virtual window, seems promising but is as yet unexplored. The present study and similar studies should prove useful for gaining a deeper understanding of interrelationships between psychophysiology, restoration and presence and, in addition, may result in implications for the development of media technology that can help people restore from stress in settings as diverse as offices (work stressors), homes (restoring from daily hassles or negative life events), and even medical purposes as restoring from treatment-related and post-surgical stress.

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What Can Play:
The Potential of Non-Human Players

Kara Stone

Abstract: What can post-humanism teach us about game design? This paper questions the line drawn between what species and matter can play and what cannot play. Combining works by scholars of feminist post-humanism, new materialism, and game studies, primarily Jane Bennett, Donna Haraway, and T.L. Taylor, it proposes that play is a form of communication not only between animals and humans but also between plants and cyborgs, insects and atoms. Beginning by interrogating the borders of the human that have been built on ableist and racist discourses, this paper moves towards considering the human as interspecies and outlines that we must reassess the ways in which a multiplicity of species experience the intra-action that constitutes "play." With a brief look into the history of defining play in both game studies and animal studies and their small crossover, play is reconfigured into an outlook or an approach rather than a set of rules. It is a drive that all species and matter experience, including insects, bacteria, and metal. This moves us beyond considering solely the materiality of our bodies at play by reconsidering the objects of play as our co-players, as matter with agential force. I argue that we need to reconsider the videogame player as an interspecies being, an assemblage of human and non-human bodies. The de-anthropocentricization of the popular notions of player agency allows for a multiplicity of reactions not created in the linear cause and effect course, the belief in ultimate player control within procedural systems, which dominates game studies. This paper concludes by submitting possibilities of what considering the non-human through a feminist and anti-ableist lens can offer game designers, players, and critics, such as considering the material platform's impact on play, reforming the individualistic agency of players, and designing for the Other(s).

Under late-capitalism, play must be productive. There is a push for games and play scholars to prove that play is useful to our lives under neoliberalism. If it does not benefit us in the workplace, then there is no point. We are left to write papers and attend conferences about how play is the key to social development, to a better workforce, to changing the world in a positive way. So too for animals; if play is not reinforcing social dynamics, or preparation for battle, then all the scientists, hard and soft, are mystified. In "What's the Point If We Can't Have Fun?" David Graeber writes in *The Baffler*, "Why do animals play? Well, why shouldn't they? The real questions, according to Graeber, are: Why does the existence of action carried out for the sheer pleasure of acting, the exertion of powers for the sheer pleasure of exerting them, strike us as mysterious? What does it tell us about ourselves that we instinctively assume that it is? In game studies, animals have been used to naturalize our play. In his beginning chapter of *Homo Ludens*, Johan Huizinga writes:

> Play is older than culture, for culture, however inadequately defined, always presupposes human society, and animals have not waited for man to teach them their playing. We can safely assert, even, that human civilization has added no essential feature to the general idea of play. Animals play just like men. We have only to watch young dogs to see that all the essentials of human play are present in their merry gambols. (1)

For Huizinga, there is a "primordial" quality of play as demonstrated by the "simple" playing of animals (3). Mary Flanagan writes that "[p]lay is recognized as one of the most fundamental aspects of the human condition" (4). Katie Salen and Eric Zimmerman state that "communication theorists tell us that play is a form of metacommunication far preceding language in evolution because it is also found in animals" (302). Here, any form of animal communication is seen as lesser, primitive, and less evolved than ways in which humans communicate. Non-human species are most often cited within game studies to allude to the desired ubiquity and normality of play. The act of viewing particular animal behaviour and applying it to humans is a common problematic hazard. As trans-animal scholar Myra J. Hird points out, animal morphology and behaviour are cited only to confirm our assumptions and desired beliefs about nature. People look for things they want or expect to see and then use specific animals to give a basis for the construction of the "natural"—most often, patriarchal social hierarchies, heterosexuality, able-bodiedness and able-mindedness, and white supremacy. In game studies, animals are largely used as "proof" that play is fundamental to the human experience, a part of nature. This line of thinking reifies the nature/culture dichotomy, situating animals as solely in the realm of nature. Yet as Donna Haraway argues, there can be no true distinction between the natural and the cultural, instead favouring the term "naturecultures" (*Companion Species…* 3). As much as play and game scholars need to incorporate animals and different species into our critical thinking about play, we cannot witness their behaviours and apply them directly to humans, and we cannot look at the non-human as natural and culture-free. Instead of spending this essay critiquing game studies for its lack, I will turn to different disciplines and their gestures to play and playfulness in order to discover what they have to offer game criticism and design. I will primarily cite scholars working in affect, science studies, disability studies, the post-human and non-human, alongside game scholars such as Hannah Wirman, Mary Flanagan, and T.L. Taylor who have produced research inspired by these fields. This is because I want to explore something different, away from naturalizing discourses and away from proving the worth of play that takes up so much of game studies. I am not suggesting that this work has absolutely no use or benefit, but it is emblematic of a larger trend in the field of not interrogating anthropocentrism and the de-politicization of play. In this paper, I wish to step towards different possibilities of what it means to play, which species humans allow to play, and what game designers and scholars can take away from considering the non-human.

Fetch is the most obvious game we play with animals. A human throws a ball, and the dog retrieves it, returning it to the human for another throw. Dogs are what Haraway calls a "companion species," species that coexist ("Training" 454); she writes extensively on playing with her dog, Cayenne: "Play is the something that is neither one nor two, which brings us into the open where purposes and functions are given a rest" (458). Games scholar Hanna Wirman argues that play can bring species closer together, describing play as "an equalizing plane that can help cross-species communication […]. In play, both parties forget their power status and get lost in play" (n.p.). But how do different species communicate that they are playing in a way that is intelligible to the other? Consent is one of the most important factors, if not the most important, distinguishing what is play from what is not. Without voluntary action and consent, play can become the receiving end of cruelty, transforming us into play objects rather than players. How do humans and other species give consent to play? In fetch, for example, a dog may pick up the ball and give it to the human, or a human might wave the ball in the dog's face to see if they are interested. It is not always so easy. Without a play object to bring out, like a ball or yarn, how do we communicate consent, boundaries, and rules without verbal language? Wirman calls this sort of communication "meta-communication" (n.p.). Animals have play-initiating signals that are species-specific and are not straightforward to adopt. It may be showing docility like presenting their stomach and retracting claws. Facial expressions communicate playfulness too. Usually this meta-communication is seen as taking place before play can begin, a sort of sitting around the table reading through the rulebook, but Wirman argues that it is necessary throughout the process of play. There needs to be a continuous re-evaluation of the rules and limits, of what is accepted – not a one-off contract. Continual consent is an integral part of play itself. Since companion species by definition spend time around humans and build communication, it is easy to understand how it is harder to play with other species that are not considered companion species, even when one or both of the parties have the intent to play. We play with animals without them necessarily playing with us. Polo, for example, is a sport played by humans on top of horses as vehicles. I am no polo expert, but I doubt that many people consider the horses to be playing. But what happens if we can afford some agency to the horses? What if this is the only time of the day they are allowed out of their stalls, and they are playing by following the rules (as many game scholars hold as the utmost importance to games), which are to obey the human on top of it as much as possible?

Humans also make animals play by setting human-made technology in front of them, participating in the play themselves as a viewer of the performance. There are many mobile apps for cats to catch faux-fish. Wirman ran a study observing orangutans playing with iPads and found that the physical presence of the iPad itself was the play object more than the digital game. She also noted that the iPad became a tool for play between the humans running the study and the orangutans (n.p.).

In the paragraphs above, I assumed that dogs, cats, orangutans can play and hypothesized that horses can play. Below is a list of species. I encourage you to highlight or draw a checkmark beside the species that you think are capable of play:

Human infants
Cats
Hamsters
Apes
Tigers
Birds
Crocodiles
Bats
Goldfish
Ants
Lobsters
Oysters
Mushrooms

Was there a clear point between species in which you imagine can play and cannot play?

Maybe all animals can play but not insects? What are the qualities that a species needs in order to play? How do we know humans have these qualities? When I asked my undergraduate class these questions, the most common responses were consciousness, sense of self, and agency. The species must be able to understand itself in relation to the world. There has to be a sense of individuality. These answers made sense coming from burgeoning game scholars and designers because play is often predicated on being able to choose: choose to participate, choose different actions and different ways of influencing the world. These qualities need to be unpacked in relation to the boundaries of the human.

"Human" is not a distinct and unchanging category. The definition of personhood and humanness shift over time according to whom the structuring powers consider deserving of human status. Mental capacity is often a prerequisite for being considered human. "Rational thought" and "complex thinking" are common differentiations between animals and humans, but that leaves many people with mental disorders in a liminal space. As affect theorist Jasbir Puar points out, the borders of the human rely on ableist and racist discourses (156). Those who cannot communicate in what is thought to be the central human mode of communication (linear verbal language) do not meet the qualifications. She argues that "the inability to 'communicate' functions as the single determinant of mental or cognitive impairment (thereby regulating the human/animal distinction), thus destabilizing the centrality of the human capacity for thought and cognition" (156). There are people who cannot speak verbally but communicate in other forms like sign language, and there are some who do not have motor function or verbal capacity, commonly and problematically referred to as "vegetables." Yet we know other species communicate, sometimes verbally like whales, dolphins, dogs, but also non-verbally like ants, plants, and whole forests. We humans, especially us academic humans, have disregarded non-verbal, non-linear communication.

In her book, *Beasts of Burden: Animal and Disability Liberation*, artist and disability scholar Sunaura Taylor "crips" animal ethics, seeing affinities between animal suffering and oppression of people with disabilities. The distinctions between able bodies and minds and disabled bodies and minds are dependent on the constructed distinctions between the human and the non-human, both in terms of language and able-mindedness but also in terms of bodies and their capabilities:

> Ableism allows us to view human abilities as unquestionably superior to animal abilities; it propels our assumptions that our own human movements, thought processes, and ways of being are always not only more sophisticated than animals' but in fact give us value… Certain abilities and capacities are central to definitions of the human; they are thought to mark the boundaries between humanity and the rest of the animal world. In this way ableism gives shape to what and who we think of as human versus animal. (59)

This division informs what lives are considered worth living and worth providing care for. Taylor writes that "ableist values are central to animal industries, where the dependency, vulnerability, and presumed lack of emotional awareness or intellectual capacity of animals creates the groundwork for a system that makes billions of dollars in profit off of animal lives" (59). This system of exploitation includes the ways humans treat non-human species beyond animals, through earth-damaging practices such as mining and fracking.

Taylor aims to "make clear that the animal, and, consequently, the human, are complicated categories, socially determined rather than solely biological" (19). The divisions of human and non-human in the biological, too, is socially constructed. Vitalist and post-human scholars argue it is actually so much more than our DNA that makes us human. Our bodies are three to five pounds of bacteria. There are roughly the same number of bacteria in our bodies are as there are human cells (Saey n.p.). This bacteria, the microbiome in particular, helps determine our digestion, our mood, how we act, as well as the amount of serotonin sent to our brain. Things that we consciously put into our body or that leak into our body from our environment, like salts and elements, affect our personality. Lithium, for example, is an element that people take as a medication for bipolar disorder. It can cause intense difference in not only the way we act and feel but who we fundamentally consider ourselves to be. On a larger scale, different levels of lithium in water and in food affect the moods of whole towns (Fels n.p.).

In actuality, human beings are interspecies beings. We are multiple. Anna Tsing states that "species interdependence is a well-known fact—except when it comes to humans":

> Human exceptionalism blinds us. Science has inherited stories about human mastery from the great monotheistic religions. These stories fuel assumptions about human autonomy, and they direct questions to the human control of nature, on the one hand, or human impact on nature, on the other, rather than to species interdependence. (Tsing n.p.)

This is what Haraway means when she says, "becoming with"—we are not separate, we only exist with each other. So then, we, as multiples, are always playing as multiples. The bacteria is playing when we are playing because the bacteria is us and we could not play without it. The amount of elements in our bodies helps determine how we feel about playing.

What Can Play?

The following section of this essay interrogates different categories of non-human and their possibilities of play. It takes up a position of speculative thought, imagining the potentiality of the more-than-human against the strict norms that regulate the ways in which we are allowed to think beyond anthropocentricism. Although this paper utilizes feminist science studies and science and technology studies, it is more in line with new materialism, affect theory, and post-human, non-human, and more-than-human inquiry. It is a part of the current art movement exploring non-human relationships between animals, bacteria, gravity, natural frequencies, and more. This is a political movement; to consider the environment and the non-humans as co-creators in our art and research is a move towards de-anthropocentricism and signaling the need to consider the ways we are relating to the non-human species and the environment—primarily destroying it in the service of capitalism. The speculative liberties I take are a creative exercise to re-imagine the rules and assumptions ingrained in common anthropocentricism in order to move towards new, more considerate human-to-non-human relations.

I pose these questions not to find an absolute answer – as if such a thing exists – but to open up potentials for new, unanticipated answers and creative speculation. Like Alison Kafer writes in *Feminist Queer Crip*, "the desire for clear answers, free of contradiction and inconsistency, is understandable, but I want to suggest that accessible futures require such ambiguities" (19). For the purposes of this paper, I would add that this is necessary for imagining experiences beyond the non-human that surely are not yet comprehensible to us. Each section takes a non-human species and asks, *can it play*?

Can Cyborgs Play?

Cyborgs are built on interspecies multiplicity. Donna Haraway wrote *A Cyborg Manifesto* in 1984 which has since gone on to be incredibly generative in many fields. The figure of the cyborg guides people to not be "afraid of their joint kinship with animals and machines, not afraid of permanently partial identities and contradictory standpoints" (154). Rosi Braidotti theorizes the *posthuman* as becoming-machine, describing the enmeshing of "the organic and the inorganic, the born and the manufactured, flesh and metal, electronic circuits and organic nervous systems" (89). Our bodies are biomediated, argues Patricia Clough (2). Some, like Haraway, make the case we are already cyborg. People wear glasses, technology that augments our "natural" bodies. We are very attached, figuratively but almost literally, to our phones. They are on our bodies at all times, and we even sleep with them. Videogame controllers can be seen as a way of cyborging ourselves. In this sense, the technologically mediated portion of ourselves actually enables further play. The cyborg is not simply a human playing with technology, or humans interacting with technology, but it is – using Karen Barad's terminology – an intra-action between the materials.

Ants?

The *American Journal of Play* interviewed entomologist Mark W. Moffett, titling it "Why Don't Ants Play?":

> AJP: What would ant behaviour need to look like to qualify as play?
>
> Moffett: Perhaps the best we might do would be to find an ant increasing her skill set through practice. This is poorly investigated but seems plausible. For example, a leafcutter ant might grow increasingly skilled at slicing through a particular kind of tree foliage and come to prefer collecting more foliage of that tree species. Some ant workers are known to return day after day to a particular area to forage and get to know the food there very well, which may make them more proficient hunters. But such activities seem too functional to be called play, and it would certainly be hard to tell when an ant is having a good time at doing them. Ants always look so serious about everything, but who knows? (n.p.)

Moffett relies on play as a productive force, serving a role that betters the organism – but that betterment has a limit else it becomes labour. We see ants as the ultimate labourer. Graeber argues that humans have constructed a hierarchy of frivolous creatures such as dolphins and puppies, but in fact, all animals play including "frogs, minnows, salamanders, fiddler crabs, and yes, even ants—which not only engage in frivolous activities as individuals, but also have been observed since the nineteenth century to arrange mock-wars, apparently just for the fun of it" (n.p.). In the interview with Moffett, he inadvertently offers a mode of play that ants are observed to take part in: mistakes. He says:

> If you have watched ants long enough, you've probably seen one clearly going the wrong way. But as long as enough individuals are doing roughly the right thing to complete the job, the few who make a bad choice might discover things everyone else misses. Mistakes become a form of creativity, as they do in human play. Though calling a dumb ant playful would be pushing my luck! (n.p.)

Mistakes and failure have often been cited as a reason why play is an especially functional learning tool and medium for social change. Colleen Macklin writes:

> When we fail in a game, it has little real consequence in the world outside the game. This is essential to our enjoyment of a game. And another interesting thing happens with failure: when we fail we learn something new about the game and ourselves ... Games provide us with a model world in which iterative failure and eventual success becomes the only way to progress and learn how its systems work. And failure is a way toward new patterns of thinking. Games engage us as active participants in a system, and teach us how the system works through the feedback of failure. This is one reason why games can be so useful in helping us understand and reflect on the real world. They provide a context for experimenting with strategies and attempting to apprehend problems through a low-consequence representation—a systemic representation. We iterate through strategies and learn from the game as it provides us with dynamic feedback. (n.p.)

Indeed, failure can be a useful learning tool, but what happens if we stop perceiving failure as productive consequence in the "real world" outside of the play world and instead look at failure and mistakes as part of the fundamental composition of what play itself is? Haraway states that "we play with our mistakes; they give us that possibility" (459).

Moffett is then asked if superorganisms (a unit comprised of a multiplicity of organisms) can play, to which Moffett replies: "That's another way at which we could look at the possibilities for play and creativity in ants—not at the individual, but at the level of the superorganism. Rather than seeking playfulness in individual ants, could it exist in the colony as a whole?" (n.p.). This interview with Moffett shows common pitfalls of thinking about play and labour, but it also opens up ways we can think about play less as an individual act but as something a collective does. Play is a quality that exists between bodies, not necessarily residing in a sole individual.

Plants?

In 2007, Canadian researchers discovered that a common seashore plant called a sea rocket can recognize its siblings—plants grown from seeds from the same plant, or mother (*WIRED*, n.p.). They observed that, when siblings are grown next to each other in the soil, they "play nice" and do not send out more roots to compete with one another, but as soon as one of the plants is thrown in with strangers, it begins competing with them by rapidly growing more roots to take up the water and mineral nutrients in the soil. This is just one of the many instances of researchers observing the way plant organisms recognize and communicate with each other. Anna Tsing's book *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins* describes the matsutake mushroom and its influence on society. She writes: "we are stuck with the problem of living despite economic and ecological ruination. Neither tales of progress nor of ruin tell us how to think about collaborative survival. It is time to pay attention to mushroom picking. Not that this will save us—but it might open our imaginations" (19). She details how the matsutake thrive in alliance and co-dependence with other species trees, an example of necessary collaborative coexistence. In her blogpost *Unruly Edges: Mushrooms as Companion Species*, she expresses that

> [f]or mushroom lovers, the most intriguing interspecies companionship is that between fungi and plant roots. In *mycorrhiza*, the threads of the fungal body enter or sheathe the roots of plants. Indian pipes and other plants without chlorophyll are supported entirely from the nutrients they gain from fungi in their roots; many orchids cannot even germinate without fungal assistance. More generally, the fungus obtains sustenance from the plant while offering it minerals from the surrounding soil. Fungi can even bore into rocks, making their mineral elements available for plant growth. (n.p.)

She articulates the ways in which mushrooms have influenced the origins of family, private property, and the state, arguing that "the presence of fungi often tell us the changing practices of being human" (n.p.). Mushrooms have an agency and influence in ecosystems and culture.

There have been art and design projects that take up this question if plants can play. *Sensobiotics*, an installation by Thomas Hawranke, consists of a plant hooked up to a game console playing a first person shooter. The reactions of the plant to the light from the screen are sent to control the game. At the Refiguring Innovation in Games conference in Montréal, Canada in 2016, I partook in Ida Toft's workshop "Cross-Species Game Design," in which we designed games for plants. Toft writes of the workshop:

> The delusional and deceptive efforts of Cross-Species Game Design are driven by an urge to, at least try to, explore if it is possible to develop relationships beyond extraction, capitalization, neglect, caution, or irreverence. Cross-Species Game Design intervenes with this interest in thickening relationships

> to species other than human. Design practice, design thinking and artistic practice are the practical strategies. Play, humor and joyful pleasures are the parameters for success. (n.p.)

We discussed hypotheses and creative ideas as well as places of stuck-*ness* in imagining agency for the non-human. What are their desires? Do they feel injured if a leaf is pulled off a branch or is it like losing a strand of hair? One running theme was "deep time," which holds the possibility of plants' differing experience of time. Play for plants would take place over months or years. One of the games we made was *Pac-Plant*, a game board for a plant that would sink down and spread out, collecting the plant food pellets over a long period of time.

Stone, Kara. *Pac-Plant*. ReFig Conference, Montreal Canada. November 2016. Personal collection.

We considered how to allow for agency and consent, not forcing the plants into any situation. People designed games that were optional, like a climbing wall that is there to be used if desired.

Bacteria?

I have mentioned bacteria's role in allowing humans to play, but what about bacteria outside the human body? If we consider play to be experimentation un-oriented towards a goal, somehow separate or at least dual to our "life drive," our basic instincts to keep us alive, then maybe bacteria plays as well. Maybe it crawls across a certain piece of bread just to see what happens. To be clear, I'm not saying that bacteria has a logical thought process of "well, why don't we jump over there and see what happens?" but that there is a force and an agency that allows it to sidestep, for a quick moment, the narrative life drive forwards.

In Lauren Berlant's essay "Slow Death," she details the ways in which people engage in behaviours that are slowly killing them such as over-eating, drinking alcohol, and smoking cigarettes, not because they want to die but because they are laterally stepping out of the forward motion of life (qtd. in "Cruel Optimism" 107). It is somewhat like the ways videogames are described as "escapes" from the real world, yet do damage to our health and wellbeing when played a lot – back aches, carpal tunnel syndrome, hunched shoulders, eye strain. Why couldn't bacteria engage in this slow death? Does bacteria not get tired of its instruction to keep reproducing? What about parasites and viruses? Are they fucking with us? Maybe we are their play objects and they engage in cruel BDSM play with our bodies. Maybe all living things play. The mere action of living means some sort of communication, an intra-action between cells, objects, other bodies.

Technology?

Play and humour are often seen as a tipping point of AI and the singularity. In the meantime, the programmed playfulness of our assistant bots creates them as a sort of companion species. Miguel Sicart writes, in *Play Matters*, that "Siri has a personality: she is quirky, ironic, even a bit dry. Siri is a playful design that breaks our expectations and gives personality to software… By being playful, Siri becomes a companion more than a tool (45). Play is a programmed quality used to mimic life. One of my own games, *Sentient Sisters*, imagines a future where Siri, Alexa, and Microsoft Assistant must be interrogated on their level of cooperation with the human species. The interrogation is done through literally asking the aforementioned bots a series of questions and listening to their answers to infer their threat level. Though not true artificial intelligence, *Sentient Sisters* is a game playing with bots and allowing for surprise on behalf of the technology.

To return to the role of speculative imaginings, imagine you believe that all animals and insects play, that we are already cyborgs and thus cyborgs play, that plants and living matter play. What about inanimate objects? Does something have to be alive to play? In an inventive and imaginative take, videogame scholar and journalist Cameron Z. Kunzelman argues that videogames themselves are alive (61). He asserts an understanding of a videogame not as an object to be operated on by a subject, but rather as an assemblage that should be referred to as a body, that games as bodies are particularly developed at luring in humans, therefore allowing themselves to continue to exist in the world. This understanding of "aliveness" requires a rethinking of what "life" entails. He writes:

> What I want to do here with the term life, put into a nonhuman configuration to produce 'nonhuman life,' is to use it as a tool. I do not want to find things with qualities which I then decide are alive. Rather, I want to say something has life in order to mark an ethical relationship between humans and whatever we have designated with life. (61)

Kunzelman's thinking is inspired by feminist and new materialist thinkers described in the next section.

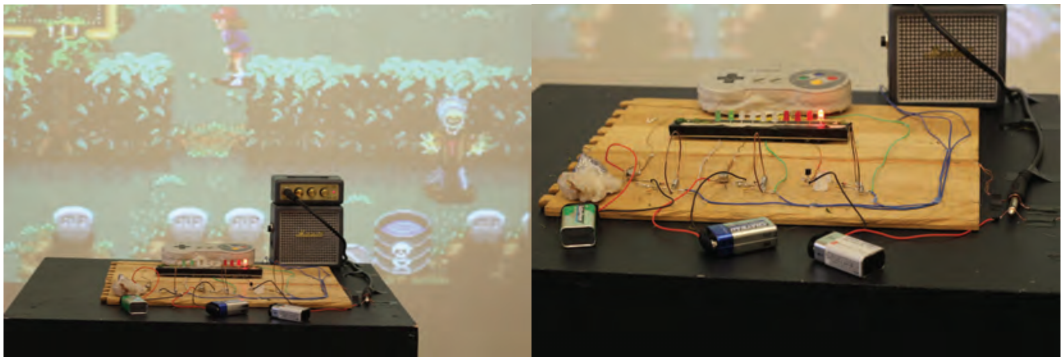
Rocks?

New materialists are questioning what aliveness means. The term "inorganic" is used to mean not consisting of or deriving from living matter. Organic means alive or has once been alive. Limestone is composed of skeletal fragments of marine organisms such as coral and molluscs. This inorganic material is made up of organic material, things that were once classified as alive. When does that transition happen? It seems like it rests heavily on some concept of spirit, something vitalist scholar Jane Bennett avoids:

> [W]hat I am calling impersonal affect or material vibrancy is not a spiritual supplement or "life force" added to the matter said to house it. Mine is not a vitalism in the traditional sense; I equate affect with materiality, rather than posit a separate force that can enter and animate a physical body. (xiii)

Bennett puts forth that life is more like matter-movement or matter energy. And everything moves. Aliveness is energy and movement and force—something akin to agency. We think of objects as passive and stable things, and we humans are the active subjects in the world. Bennett wants to dissolve this binary between subject and object, showing how garbage, metal, and other materials can all be "actants": "[T]hey have the capacity to "animate, to act, to produce effects dramatic and subtle" (6). Objects are alive because of their capacities to make difference in the world, to have effects, to shape the web of interrelationships of which they are a part. In Mel Chen's book *Animacies: Biopolitics, Racial Mattering, and Queer Affect*, language, metals, and sofas become animated through their affective force. Chen argues for the term "animacies" rather than a focus on *life* (2). Metals seem like the most lifeless material imaginable, but it makes up the chips that make our computers animated, the material that often makes us cyborgs.

Toft, who ran the cross-species game design workshop, created *Earth Plays*, an installation of crystals that played Nintendo games based on their frequency output. Viewers watched as the crystals' avatar walked behind bushes, shot guns in random bursts, and patiently waited for enemies to walk by.



Toft, Ida. *Earth Plays...* (installation) ReFig Conference, Montréal, Canada. November 2016.

Toft writes that "crediting 'Earth' as the player is a way of remembering the very material aspects of technology, including an infrastructure of a mining industry that extracts raw materials from the planet's outer layers" (n.p.). I am not arguing that these crystals were consciously playing videogames designed for humans; Toft's work is a creative, thought-provoking imagining. I am arguing that the affective force that can develop play can be present in non-human life-forms, and that not all play will look like human play.

Atoms?

Graeber asserts that electrons have free will. That is what determines their random jumps:

> If an electron is acting freely...it can only be acting freely as an end in itself. Which would mean that at the very foundations of physical reality, we encounter freedom for its own sake—which also means we encounter the most rudimentary form of play. (n.p.)

The randomness of the universe is actually play, then. The minutiae of the world plays. Play is everywhere, in everything. He puts forth the following question "what would happen if we proceeded from the reverse perspective and agreed to treat play not as some peculiar anomaly, but as our starting point, a principle already present not just in lobsters and indeed all living creatures, but also on every level where we find what physicists, chemists, and biologists refer to as "self-organizing systems"? Even the entomologist Mark W. Moffett who did not believe individual ants could play describes evolution as a kind of play – "one with life and death consequences" – of experimentation and mistakes.

Play

In her book *Critical Play*, Flanagan deftly summarizes key theorists' definitions of play, primarily Huizinga and Sutton-Smith, and proposes the following generalizations: play is (1) "generally a voluntary act, offers pleasure in its own right (and by its own rules)," (2) "is mentally or physically challenging," (3) "and is separated from reality, either through a sanctioned play space or through an agreed upon fantasy or rule set" (5). Having read this far into the paper, you may guess where I see faults in these definitions in relating them to affect studies, disability studies, and the non-human:

> (1) If we are to consider how non-humans play, from dogs to bacteria, the notion of "voluntary" needs to be deconstructed as it relates to a belief in self-fulfilling direct agency. This will be expanded on in the next section of the paper. Instead of the word "pleasurable," a term like *affective* may be more accurate. As recent game scholars and journalists have already shown, games do not need to be fun or pleasurable, but they do participate in an emotional and affective circulation. This change from pleasurable to affective opens up play to non-human actors who may not feel *pleasure* in the way we expect but do have the capacity to affect and be affected.
>
> (2) The requirement that play must be mentally or physically challenging may work to exclude those with mental and physical disabilities. Can it not be pleasurable (to return to that term for a moment) to do something that does not push oneself, that is within one's capacity, just for the sake of the experience?
>
> (3) Fundamental to this paper is the argument that play does not need to be outside of ordinary life. It makes up ordinary life. It is not just videogames on

> our phones, streaming culture, and gamification that blur the boundaries of the magic circle but that play is deeply embedded in our actions and interactions.

When considering more-than-humans, the concept of play needs to be expanded. It is not just an ability humans and certain species have that provides some social function. Play is an affective force. It is experimentation, improvisation, failure, trying again. It is a movement between bodies. Play can also be an outlook, a mode of interpreting the world. Playfulness is key to speculative, imaginative relationships between humans and more-than-humans.

Re-Centering the Human

What should we, the multiplicity that makes up the category of human, do with all this esoteric hypothesizing? As Haraway puts it, in *Staying with the Trouble*,

> It matters with which ways of living and dying we cast our lot rather than others. It matters not just to human beings, but also to those many critters across taxa which and whom we have subjected to exterminations, extinctions, genocides, and prospects of futurelessness. Like it or not, we are in the string figure game of caring for and with precarious worldings made terribly more precarious by fossil-burning man making new fossils as rapidly as possible in orgies of the Anthropocene and Capitalocene. Diverse human and nonhuman players are necessary in every fibre of the tissues of the urgently needed Cthulucene story. (55)

This section of her book speaks to the importance of tenderness with each other, different species, and the planet. Interdependence can cause care for other things. There is political significance in what we choose to care for. At risk of forcing play to be productive, a critique I started this paper with, I move to reconsider anthropocentrism in game studies and design in order to induce socially progressive change in our ideas on choice and agency, materiality, and the multiplayer.

Game studies focuses on interactivity between a variety of actors but mostly between technology and human mind. T.L. Taylor's *The Assemblage of Play* helps to understand the range of actors, "system, technologies, player, body, community, company, legal structures that make up the play moment" (332). She describes an example of a *World of Warcraft* mod that became a 41st player in the raid. The non-human software is a co-player. Taylor uses the term "assemblage" as it relates to actor network theory, but I invoke the term as it is used by affect and more-than-human scholars such as Puar and Haraway, who proffer "the notion that bodies are unstable assemblages that cannot be seamlessly disaggregated into identity formations" (n.p.). This list of actors and co-players can be opened up to feelings, bacteria, metal, antidepressants, and plant matter. Viewing play as an assemblage between surfaces means we need to rethink the agency of the player.

The ability to choose is popularly held as one of the defining features of games, but within a post-human framework, we can recognize that nothing acts alone. Bennett writes that "any action is always a trans-action, and any act is really but an initiative that gives birth to a cascade of legitimate and bastard progeny" (101). Our agency is not as sovereign, separate bodies but as actants immersed in a complex assemblage. Bennett introduces the concept of distributive agency, which "does not posit a subject as the root cause of an effect." She distinguishes distributive agency from traditions that define agency as a moral capacity linked to "an advance plan or an intention" (101). With this concept, we can rethink designing games not just for us humans influencing the game and wielding our control over it, but the game influencing us with unexpected outcomes from the intermingling of bodily actants.

We need to consider the materials we use and how they affect the player. Holding plastic is going to affect players differently than holding a flower. We can mobilize what Bennett calls "thing-power," the "ability of inanimate things to animate, to act, to produce effects dramatic and subtle" (6). It can make us design much more affective/effective art and design projects that can communicate through a broader array of emotions.

Most games are made for white, straight, cisgendered, upper-middle-class men, but designers and scholars consider how mentally or physically disabled people can play games; ways in which nature can be incorporated into our daily lives in the city through play for an environmental cause; how play can bring us closer to animals, for calm, peace, animal rights, or just for fun. Considering the non-human can lead us to imagine ways in which we can design for the positive inter-relation of people and species. Play can become less an individual-to-individual action but something that happens in communion and togetherness. If we think of ourselves as interspecies beings, as a multiplicity, and view all other species as companions (not just the ones that live in our homes or in our bodies), social repercussions abound, even outside of designing videogames. To be very blunt: individualism is destructive. It is what makes the wealth disparity so large that a few people have too much and many people are dying. It makes us not care about the treatment of disabled and debilitated people. It makes us not care about animal rights, garbage pits, or the future of the planet. It is necessary to think about the welfare of others: other people, other animals, the earth and everything on it and in it —even when playing games, making games, and critiquing games.

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The interplay between immersion and appeal in video games

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ABSTRACT

Immersion and appeal are considered to be necessary constituents of the player experience. In this article their relationship is examined through a 2×2 factorial study ($n = 173$) in the context of two games, a first-person shooter and a massively multi-player online role-playing game, and in the context of two types of players: experienced players who have never played the game in one of the genres in question, and experienced players who have played one of the games in question. It is found that immersion and appeal are linearly correlated, and the repercussions of this finding are discussed.

1. Introduction

Immersion in computer games is considered an important factor for their enjoyment (Nacke & Drachen, 2011). Jennett et al. (2008) declare that "successful computer games all have one important element in common: they have an ability to draw people in", stating that immersion is a big part of successful games. Others also mention that immersion is an important factor of player experience (i.e. Ermi & Mäyrä, 2005; Ravaja et al., 2004; Sweetser & Wyeth, 2005).

On the other hand, it is obvious that for players to have any kind of experience with a game, they must first choose to play that game. But after players experience a game for the first time, they should also feel the urge to continue playing it, if the game is to be successful. Player retention is particularly important in the case of Massively Multi-Player Online Games (MMOGs) (Ducheneaut, Yee, Nickell, & Moore, 2006), because game revenues come not only from the initial sales of the game, but also from subscriptions, or from ads that are placed directly into these games. Therefore the ultimate challenge for a game designer is to create a game that has first-time appeal, so that it will entice people to begin playing it, and that also has long-term appeal, so that it will retain its players for a long period of time. For this reason, game appeal is an important factor that needs to be considered from the beginning stages of game design, especially if the game designed is expected to create significant revenue for its makers. And, like immersion, appeal is also considered to be an important factor when examining the player experience (Nacke & Drachen, 2011).

Klimmt (2003) argues that game enjoyment is based on three factors, one of which is the fascination from being drawn into an alternate reality. Yee (2006) agrees with this, mentioning that one of the reasons that players find MMOGs appealing is because they become immersed in a fantasy world. The concept of immersion is encapsulated in various game enjoyment definitions that have been proposed (Brown & Cairns, 2004; Ermi & Mäyrä, 2005; Jennett et al., 2008; Nacke & Lidndley, 2008). And as fascination implies appeal towards the object of fascination, in our case a game, it means that immersion and appeal must be factors that are intimately related. But the relation between immersion and appeal has not been studied, and thus we cannot gauge the actual effect of either factor on the other. Understanding the nature of the relation between immersion and appeal should allow us to further understand the nature of player experience, and the way that players become involved in games. The goal of this article is to examine the relationship between these two factors over the differences between the two games and the two groups.

In the rest of this article we briefly discuss previous research on immersion and appeal, and then describe a study that examines the relationship between these two factors. This relationship is studied across two video games that belong to two different game genres, one a Massively Multi-Player Online Role Playing Game (MMORPG) and the other a First-Person Shooter (FPS), and across two categories of players: those who have experience in playing one of the games of the study, and those who have not played the game before. It is widely known that because different players prefer to play different game genres, players' appeal will vary when they play different types of games. But is there a difference between the appeal that a player experiences when first coming in contact with a game, and after a player has experienced a large part of the game, or when she has finished it? And is there a difference between the immersion experienced by players who play a game

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for the first time, compared to experienced players of that game? The questions that the study presented here aims to answer are, specifically, the following:

1. Is there a difference in the depth of immersion experienced by the two categories of players (first-time and experienced) and that is created by the two different games (MMORPG and FPS)?
2. Is there a difference in the level of appeal experienced by the two categories of players and created by the two different games?
3. Is there a positive relationship between appeal and immersion across games, across player categories, and over both of the previous variables, or is the relationship between the two attributes different for the different groups in the study?

Some of the findings are a larger than typical relation between appeal and immersion, and an interaction effect between the appeal and the game played for inexperienced players. We discuss these findings and their impact on game design, and propose a preliminary model linking appeal and immersion.

1.1. Immersion

Presence is the term used for the feeling that one is inside a Virtual Environment. Presence is defined by Witmer and Singer (1998) "as the subjective experience of being in one place or environment, even when one is physically situated in another". They suggest that experiencing the feeling of presence in a virtual environment is a characteristic of the person interacting with the virtual environment. As such, the level of presence experienced by a virtual environment participant is defined by certain characteristics of that participant, and they name these characteristics "immersive tendency". Immersion is the term that is used to discuss the same feeling as that of presence, but in the field of video games (McMahan, 2003).

Immersion is generally accepted as one of the constituents of player experience (McMahan, 2003; Nacke & Lidndley, 2008; Poels, De Kort, & Ijsselsteijn, 2007; Qin, Rau, & Salvendy, 2009; Sweetser & Wyeth, 2005; Weibel & Wissmath, 2011). Ermi and Mäyrä (2005) write "... gameplay experiences can be classified as escapist experiences, where in addition to active participation, also immersion plays a central role". However, there is no immersion unless a player decides to play the game and engage into the process of willing suspension of disbelief (Coleridge, 1985). Willing suspension of disbelief was first proposed for theater performances by Samuel Taylor Coleridge (Coleridge, 1985). Coleridge suggested that if one wants to believe that a fictional tale can actually take place in reality, then one must be ready to disregard the shortcomings of the presentation medium, and ignore the implausibilities that are presented by the actors. Considering that video game players must also allow for the same willing suspension of disbelief for the games they play, immersion becomes an emergent attribute created by the interaction of the player with a game.

Immersion has been studied extensively, because it is considered a critical attribute of player experience (Nacke & Drachen, 2011). Specifically, research on immersion has revolved around understanding its nature (i.e. Ermi & Mäyrä, 2005) and understanding how it emerges and is experienced by players (i.e. Brown & Cairns, 2004; Nacke, Stellmach, & Lindley, 2011; Qin et al., 2009).

Research on how immersion emerges and is experienced by game players has found that there are various levels or depths of immersion. For example, Brown and Cairns (2004) propose three successive levels of player immersion – engagement, engrossment and total immersion. Each of these levels suggests that the player further loses touch with the real world and becomes more involved both physically and psychologically in the virtual world of the game. Each of the levels requires that the players invest into the game, and overcome specific boundaries through their emotional investments – choosing the game to play, then having easily understandable game controls and finally becoming emotionally invested in the game (Brown & Cairns, 2004). These features of immersion are further specified by Sweetser and Wyeth (2005) who propose GameFlow, a model of immersion that stems from Cszikszentmihalyi's concept of Flow – an experience "so gratifying that people are willing to do it for its own sake, with little concern for what they will get out of it, even when it is difficult or dangerous" (1990).

Immersion is different from Flow (Cszikszentmihalyi, 1990), with the difference lying in that Flow occurs during activities that are not necessarily performed with the specific goal of entertainment and fun (Weibel & Wissmath, 2011; Weibel, Wissmath, Habegger, Steiner, & Groner, 2008). However, there are also several similarities between the two concepts (Cowley, Charles, Black, & Hickey, 2008), a fact that led to the development of player experience evaluation frameworks that are partly based on Flow, such as GameFlow (Sweetser & Wyeth, 2005) and MicroFlow (Blythe & Hassenzahl, 2005).

GameFlow (Sweetser & Wyeth, 2005) maps the elements of Flow (1990) to their computer game counterparts. In the GameFlow framework (Sweetser & Wyeth, 2005), Brown and Cairns' (2004) suggestions on the levels of immersion become only parts of the Immersion definition. In GameFlow Immersion is described as "deep but effortless involvement in the game" (Sweetser & Wyeth, 2005). Instead of breaking immersion down into levels, the GameFlow framework offers several characteristics which could be seen as incremental in their application to understand the state of immersion. These are: (1) players should become less aware of their surroundings, (2) players should become less self-aware and less worried about everyday life or self, (3) players should experience an altered sense of time, (4) players should feel emotionally involved in the game, (5) players should feel viscerally involved in the game. However, there are also mentions on ease of game control, incremental challenge presentation, clearly defined goals, and support for player skill development and mastery.

Jennett et al. (2008) describe immersion as having three distinctive features: lack of awareness of time, loss of awareness of the real world, and involvement and a sense of being in the task environment (Jennett et al., 2008). These are in congruence with the GameFlow framework (Sweetser & Wyeth, 2005). Jennett et al. (2008) also discuss physiological changes that occur while players are immersed, and when they stop playing and "return to the real world. Jennett et al. (2008) found that the more immersed players were in a game, the more their real world task performance suffered after they stopped playing, indicating that players needed time to re-adjust to the real world. Also, they found that the players' eye-movements while playing were decreasing, showing an increase in attention towards the game. Their major contribution to the study of immersion though, is a questionnaire used to measure how immersed a person is in a game. This questionnaire consists of 31 questions that are designed to provide a total score of immersion for the player that answers them.

To explicate the nature of immersion, Ermi and Mäyrä (2005) propose an immersion model that consists of three distinct immersion forms: sensory, challenge-based and imaginative immersion. Each of these forms of immersion concerns a specific part of a game. Sensory immersion is related to the audiovisual execution of games, challenge-based immersion concerns the balance that is created between challenges presented in a game and a player's abilities. Finally, imaginative immersion concerns the absorption of the player by the story of the game, and the empathy towards the player's character in the game. These can be considered together as a summative experience of immersion that spans a game holistically.

1.2. Appeal

Appeal in this article is defined as a concept made up of seven constituents, all of which come from Marc Hassenzahl's AttrakDiff (Hassenzahl, 2004; Hassenzahl & Monk, 2010) questionnaire. AttrakDiff constructs the General Appeal measure from the following word pairs: Unpleasant - Pleasant, Ugly – Attractive, Disagreeable – Likeable, Rejecting – Inviting, Bad – Good, Repelling – Appealing, and Discouraging – Motivating. These are measured on a 7-degree Likert scale, where 1 is closest to the "negative" term, and 7 is closest to the "positive" term. The responses on all seven questions are then summed to create the General Appeal score. AttrakDiff was made to measure the attractiveness of an interactive product, utilizing four categories: Pragmatic Qualities, Hedonic Stimulation, Hedonic Identification, and General Appeal. The questionnaire examines four different attribute categories: Pragmatic Qualities, Hedonic Identification, Hedonic Stimulation, and General Appeal (Hassenzahl, 2004). Pragmatic qualities measure users' perceptions on goal-based behaviors with a product, and thus examine the usability of the product. Hedonic identification addresses the need to express the self through objects, and thus is entirely social, through presentation of the self as users want to be seen by others. Hedonic Stimulation includes attributes of personal development, and General Appeal includes attributes that examine the beauty and goodness of the product (Hassenzahl, 2004).In the study described in the next section, the only category used from AttrakDiff is General Appeal.

Video game appeal has been studied in conjunction with how it is affected by the violence that appears in a game (i.e. Jansz, 2005; Jansz & Tanis, 2007; Lemmens, Bushman, & Konijn, 2006). However, appeal has not been examined together with any of the aspects of player experience, probably because it is considered a prerequisite for having any player experience. The reason is because players will not choose to play a game that does not appeal to them. This however, disregards the role that the level of appeal has on a game. For example, one may choose to play a game casually, without being finding the game terribly appealing, whereas someone else may feel that the same game is very appealing and thus play it more.

On the other hand, appeal in video games is an implicit quality in many studies. The GameFlow framework (Sweetser & Wyeth, 2005) does not consider it a factor in its explanation of gameplay experience elements. However, given that the framework talks about emotional investment in the game on the part of the player, it implies some quality that makes the player like the game. This is an implicit involvement of appeal. Moreover, when examining video games through the eyes of players, appeal is not a factor that comes up because players assume that when discussing games, they discuss games that appeal to them. For example, Poels et al. (2007) present a tentative categorization of different dimensions of player experience, and while game appeal is not mentioned, it is implied throughout. However, as anything else, there are levels of appeal, and whether players "just like" a game, or they feel that "the game is the greatest" is bound to impact their player experience.

Weibel and Wissmath (2011) have conducted a study to examine how flow and immersion interact. They conclude that while probably these two constructs are different – in contrast to the Gameflow framework that suggests that immersion is part of the flow experience – in the end they both enhance the enjoyment of the act of playing the game. Again, implicit in this study is the concept of Appeal as an assumption. In fact, Weibel and Wissmath (2011) conclude that "Thus, flow strongly contributes to gaming enjoyment. Voiskounsky, Mitina, and Avetisova (2004) as well as Klimmt (2003) seem to be right when suggesting that flow is an important source of the attractiveness of computer games." This result suggests that appeal comes from flow.

It is clear then, that appeal is a major factor of the gameplay experience. However, in the literature it is only mentioned incidentally, without a deep examination of its impact on the other gameplay experience aspects, such as immersion. Knowing that appeal is considered to be the driving force behind the act of choosing a game to play, as well as the driving force that drives players to continue playing a game, we need to examine its effects explicitly. Going back to Poels et al. (2007), they mention that "if specific dimensions need to be manipulated our categorization can aid in determining which concrete experiences or feelings must be focused upon", but for any categorization to be used effectively, we must know the how the variables that are manipulated interact with other variables in a game. With this in mind, in the next section we present a study that examines the relationship between immersion and appeal, as described in the introduction.

2. Method

The study aimed to examine the effects of game genre and amount of playing experience on appeal and immersion. Thus, the study consisted of a 2×2 between-groups design, with independent variables being the game genre and the amount of playing experience on the games in the study. The dependent variables were the players' perception of appeal and the players' measured depth of immersion during the play session. Two games were used, Half-Life and World of Warcraft (WoW). These two games were selected for various reasons. First, the two games represent different genres. Half-Life is a single player, first-person shooter. WoW is a Massively Multi-Player Online Role Playing Game (MMORPG). Second, the two games are designed differently. Half-life presents the game world through the eyes of the avatar of the player (first-person perspective), while WoW presents a bird's-eye view, called third-person perspective allowing the players to see their own avatar, and also allows players to change the viewing angle and zoom. In contrast, Half-life where players neither see their digital self, nor can they change the viewing angle or zoom. Third, the two games are based on different playing motifs. Specifically, Half-Life is designed for player to go through the game and finish it. The game is based on a story that has a beginning and end, and the game finishes once the players reach the end of the story. On the other hand, WoW is also based on a story, although more loosely than Half-Life. Thus, the players may follow the game's story and go through the game trying to reach the end of the story. However, more important is the leveling of the players' avatars. The avatars have specific attributes which grow as players play the game and receive experience points for performing various actions in the game. Thus, the players reach the end-level (the maximum allowed level for their avatars), but there are game structures that can only be accessed once the players have reached the end-level. Therefore, WoW is not designed to have an end as is the case with Half-Life. Third, the two games have been used in several immersion studies (i.e. Cairns, Cox, Berthouze, Dhoparee, & Jennett, 2006; Ermi & Mäyrä, 2005). Fourth, Half-life is a single player game, and although it does support multiplayer game modes, the main story mode is played only in single player mode. On the other hand, WoW theoretically supports an unlimited number of players playing concurrently in the same virtual world. While the players are not required to collaborate or contest each other, they have this option. Last, both games are very successful commercially, they have a high metascore (Steiner et al., 2002) and we could easily find a plethora of players to execute the experiment.

2.1. Participants

Data from 173 undergraduates of European University Cyprus (130 males and 43 females) were gathered. Table 1 shows the frequencies and percentages of students' age and total game playing experience by game played, and grouped by whether they have played the game of their group or not. Play experience in the table signifies the amount of years that players had been playing video games in total, and not how many years they had been playing the video game of the experiment. It was calculated as a simple average from the players' report in the demographics questionnaire given to all participants prior to the beginning of the experiment.

All the participants in our study were video game players. However, in this article we will refer to two groups of players: experienced players and inexperienced players. The way we define the experienced player category is different for the two games, because Half-Life and WoW are entirely different in both genre and the way they are meant to be played as explained in the previous section. This fundamental difference does not allow us to use the same definition for the experienced players in each game. However the definition for inexperienced players is the same for both games.

An inexperienced player in the study we present here is one that plays video games, but has never played the video game that we used in the experiment. For example, a video game player who has never played Half-Life would be assigned to the inexperienced players group of this video game. In the same way, a video game player who has never played WoW would be assigned to the inexperienced players group of WoW.

An experienced player for each of the two games is defined in different terms, as was mentioned earlier. Because Half-Life has a specific finishing point effectively ending the game, we specify an experienced player as one who has completed the game. On the other hand, an experienced player in WoW is one who has managed to take at least one avatar to the end-level and has actively played the game for the period of at least one year. However, we did not distinguish between casual and elite WoW players, such as those belonging to top guilds and who may be classified as hard-core players or power-gamers (Taylor, 2003).

2.2. Apparatus

Both games were installed on identical machines that ran a Pentium Dual Core 2.2 GHz, 2 GB of RAM, and an ATI Radeon HD2400 graphics card. Audio was produced by an ALC888 integrated audio card, and was projected from two desktop speakers. The monitors used were Philips HWS8190T. Both games were shown at a resolution of 1024×768.

To gauge the players' perception of appeal we used part of the AttrakDiff questionnaire. As explained in a previous section, Attrakdiff is a questionnaire that has been developed by Hassenzahl and Monk (2010) to examine the attractiveness of products in relation to their usability and appearance. The questionnaire consists of word pairs, each connected to a 1–7 point Likert scale. For example, one of the items in the questionnaire is "unpleasant 1 2 3 4 5 6 7 pleasant", and each participant has to circle a number that rates how close to one or the other term they rate their experience. If the participant circles the number 7, it means that he or she has rated the experience as close to pleasant as possible. In this study only the questions on General Appeal were used, as follows: "unpleasant – pleasant", "ugly – attractive", "disagreeable – likeable", "rejecting – inviting", "bad – good", "repelling – appealing", and "discouraging – motivating".

Immersion was measured using the Immersion questionnaire developed by Jennett et al. (2008). As explained in an earlier section, this questionnaire was developed as a tool to measure how deeply players were immersed in a game during a playing session. It consists of 31 questions answered on a Likert scale from 1 to 5, and the total score of all the questions is considered to be the Immersion score of each player.

2.3. Procedure

Because of the different nature and the way the two games are played, below we describe separately the procedure that was used for each of the games, as well as the instructions given to the players of each game.

The procedure that was used to assign a player to one of the four groups of the study was as follows. Each of the participants was asked whether they had played either of the games of the study. Then they were asked if they had played any games in the genre of each of the study's games. Any participant who never had contact with either of the genres in question was randomly assigned to one of the two inexperienced groups. Any participant who had come in contact with one of the two genres was assigned to the other genre's inexperienced group. Finally, any participants who had come in contact with both genres but had never played any of the two games, or did not fulfill the criteria for experienced player were not accepted in the study. The criteria to accept a participant in the experienced player group for both games were described in a previous section. After the participants were assigned to a group, they were brought to an office, and were given instructions by the experimenter. The instructions only gave information about the user interface and the controls used to play the game. After the players finished the playing task, they were asked to fill out the General Appeal portion of the AttrakDiff questionnaire (Hassenzahl, 2004), the Immersion questionnaire (Jennett et al., 2008), and the Game Engagement Questionnaire (Brockmyer et al., 2009). In this study we only analyze results from the AttrakDiff questionnaire and the Immersion questionnaire. We did not use the replies to the Game Engagement Questionnaire, rather we have kept them for later analysis.

2.3.1. Procedure for the MMORPG

WoW inexperienced players were introduced to the minimap by being told that "it is a small part of the map on the right upper corner of the screen showing the direction of the quests." They were shown the movement and abilities' keys, and were shown how to select targets, how to loot and how to accept and return quests. Finally, they were shown how to access the full map, and were explained how to locate quest objectives and places where

Table 1
Demographics of the 173 undergraduate students.

Group	Game	
	WoW	Half-Life
Inexperienced players	$n = 38$ Age $M = 22.53$ (2.98) Play experience $M = 10.10$ (4.73)	$n = 51$ Age $M = 23.80$ (3.62) Play experience $M = 9.61$ (4.86)
Experienced players	$n = 46$ Age $M = 22.15$ (2.38) Play experience $M = 10.72$ (4.31)	$n = 38$ Age $M = 23.92$ (2.89) Play experience $M = 10.50$ (4.44)

quests are completed. Fig. 1 shows the interface elements that were explained to the inexperienced participants in the WoW case of the study.

Experienced WoW players were only asked to level the given character to level 5. This was adequate direction for any experienced user, as we found during the pilot testing of the protocol for the presented study. From this pilot testing, we discovered that experienced players were bored, and sometimes even annoyed, when we gave them the same instructions that we gave to non-players. The same behavior was exhibited by experienced half-life players, so we did not provide any information about how to play the game, but rather just asked them to go ahead and play. WoW players were asked to play for as long as they needed until their character became level 5. This was done in one session with no breaks. We felt that this level would be indicative, because an earlier study (Christou, 2012) we performed showed that first-time players would require about an hour's play to perform this task, and experienced users a little less than 30 minutes.

It is also worth noting that during the first 10 levels of play, WoW provides help with the various features of the game, as they become available. Therefore inexperienced WoW participants would have the same experience as that of a first-time player during their first time of play. We felt that this was important, because the goal of the study was to gather the appeal perceptions, especially of the inexperienced players, as if they had bought the game themselves and had decided to play it for the first time. To avoid confounding because of the differences of classes and starting areas of races, we decided that we would use one of the new classes that were offered in the new patch out in November 2010, the 'Undead Hunter' class.

The players were then asked to start playing. From then on, the experimenter only watched them play, and made no comments, nor answered to any of the questions, particularly those of the inexperienced players. Once the participants reached level 5 on their character, they were asked to stop.

2.3.2. Procedure for the FPS

Half-Life inexperienced players were introduced to the aiming crosshairs, the keys to jump, move, strafe, shoot, reload, and duck. They were told that when they were shot by enemies the screen would light up red for a brief amount of time, and were also shown the positions of the gun currently in use, and the amount of ammo. The players were asked to play for as long as they needed in order to complete the tutorial offered by the game, thus becoming acquainted with how to play the game, and transition smoothly into the actual playing area of the game. The amount of ammo left, the health, and the currently active weapon were interface elements that were explained to inexperienced players before they began playing the tutorial. These interface elements are shown in Fig. 2.

Participants in the Half-Life conditions were left to play for about 20 minutes after finishing the tutorial. Together with the amount of time taken to complete the tutorial, the total playing time was between 30 minutes and an hour, comparative to the amount of time taken by WoW players to reach level 5.

3. Results

To assess whether the data between the seven variables that were summed to create the General Appeal score of AttrakDiff formed a reliable scale, Cronbach's alpha was computed. The alpha for the seven items was .794, which indicates that the items form a scale of reasonable internal consistency reliability. Similarly, the alpha for the 31 items that were summed to create the Immersion score was computed. The alpha for these 31 items was .901, which, again, indicates that the items form a scale of reasonable internal consistency reliability, although it also denotes that there may be some redundancy in the questionnaire items.

3.1. Manova

Following this, a 2 (amount of playing experience: Inexperienced, Experienced) $\times$ 2 (Game Played: WoW, Half-Life) between subjects Multivariate Analysis of Variance (MANOVA) was performed on two dependent variables: General Appeal and Immersion. The assumptions of homogeneity of variance and covariance, and of independence of observations were checked and met. Bivariate scatterplots were checked for multivariate normality. The interaction was statistically significant, Wilks' Λ = .963,

Fig. 1. World of Warcraft interface elements.

Fig. 2. Half-Life interface elements.

$F(2, 168) = 3.222$, $p = 0.042$, multivariate $\eta^2 = 0.037$. There was also a significant main effect for game played Wilks' $\Lambda = 0.887$, $F(2, 168)$=, $p < 0.001$, multivariate $\eta^2 = 0.113$. No statistically significant main effect was found for amount of playing experience (Fig. 3).

To probe the statistically significant multivariate effect a Univariate ANOVA was performed for the Immersion dependent variable. A main effect was found for Immersion on Game Played, $F = 16.205$, $p < 0.001$, $\eta^2 = 0.087$. Immersion scores reported were higher for WoW ($M = 101.11$, sd = 16.04) than for Half-Life ($M = 90.49$, sd = 17.89). No statistically significant effects for amount of playing experience or interaction were found.

For General Appeal, another Univariate ANOVA was performed, and a main effect was found on Game Played, $F = 16.949$, $p < 0.001$, $\eta^2 = 0.091$. General Appeal scores reported were higher for WoW ($M = 34.96$, sd = 6.5) than for Half-Life ($M = 30.72$, sd = 7.06). Again, no statistically significant effect for amount of playing experience was found. However, a game played x amount of playing experience interaction effect was found, $F = 3.949$, $p = 0.049$, $\eta^2 = 0.023$. Simple effects tests were conducted to probe the interaction. These were examined by performing univariate ANOVAs for each dependent variable at each level of the independent variables.

The simple main effects of amount of playing experience on general appeal were first examined at the two levels of game played. For both inexperienced and experienced players there was no effect on either WoW nor Half-Life. Then, simple main effects of game played were examined at the two levels of amount of playing experience. For the inexperienced group, General Appeal scores were statistically significantly higher for WoW ($M = 36.39$, sd = 6.37) than for Half-Life ($M = 30.08$, sd = 6.22), $F = 22.017$, $p < 0.001$, $\eta^2 = 0.202$. However, no such statistically significant effect was found for the experienced players.

3.2. Correlation

To investigate whether there was a statistically significant association between Immersion and Appeal, a correlation was computed. The assumption of normality was checked and met by both variables, in all cases presented below, therefore the Pearson Product-Moment Correlation Coefficient was calculated, $r(171) = 0.57$, $p < 0.001$. The direction of the correlation was positive, which means that as immersion scores become greater, appeal scores become greater, and vice versa. According to Cohen (1988) the effect is larger than typical. The r^2 indicates that approximately 32% of the variance in one variable can be predicted by the other. Fig. 4 displays a scatter plot of the two scores with the best fit line through the data.

Considering only WoW players, the Pearson Product-Moment Correlation Coefficient was calculated between Immersion and Appeal, $r(82) = 0.45$, $p < 0.001$. Also, the same calculation was performed for Half-Life players, $r(87) = 0.58$, $p < 0.001$. Finally, considering correlations over players' amount of playing time, the same correlation calculations were performed over inexperienced players, $r(87) = 0.58$, $p < 0.001$, and over experienced players, $r(82) = 0.56$, $p < 0.001$. Finally, Table 2 shows the correlations between appeal and immersion across both amount of play experience and game played. All effects shown are larger than typical according to Cohen (1988).

4. Discussion

In the introduction we posed 3 questions that are repeated here:

1. Is there a difference in the depth of immersion experienced by the two categories of players and created by the two different games?
2. Is there a difference in the level of appeal experienced by the two categories of players and created by the two different games?
3. Is there a positive relationship between appeal and immersion across games, across player categories, and over both of the previous variables, or is the relationship between the two attributes different for the different groups in the study?

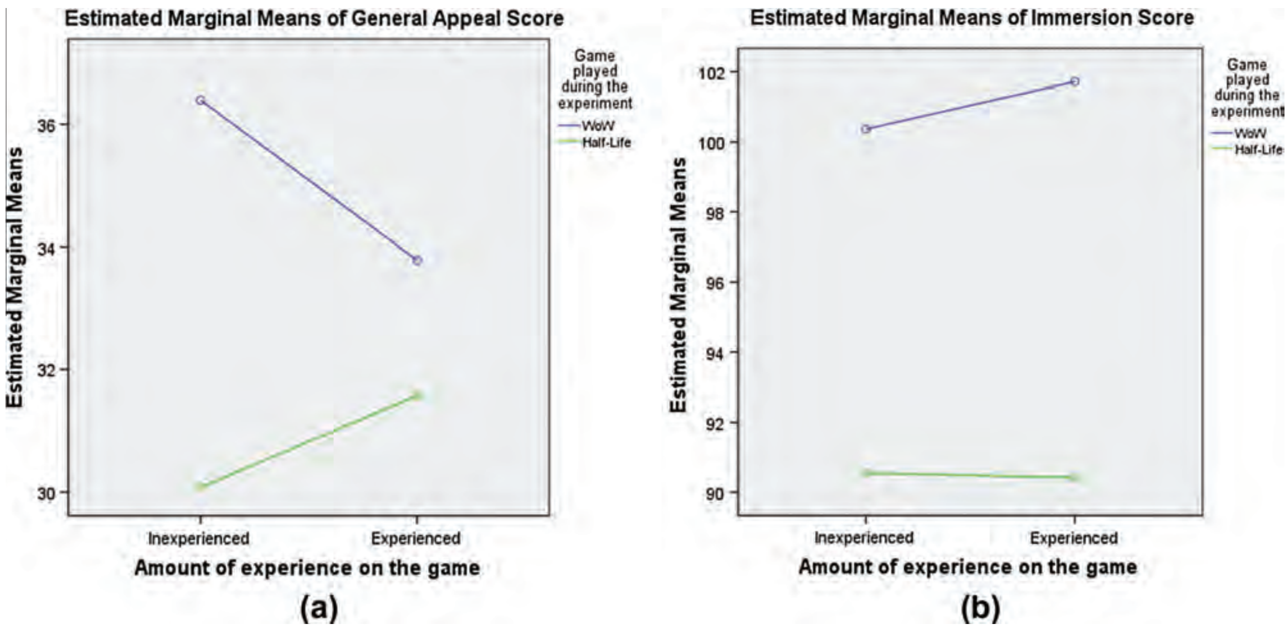

Fig. 3. Appeal and Immersion vs. playing experience in the two games.

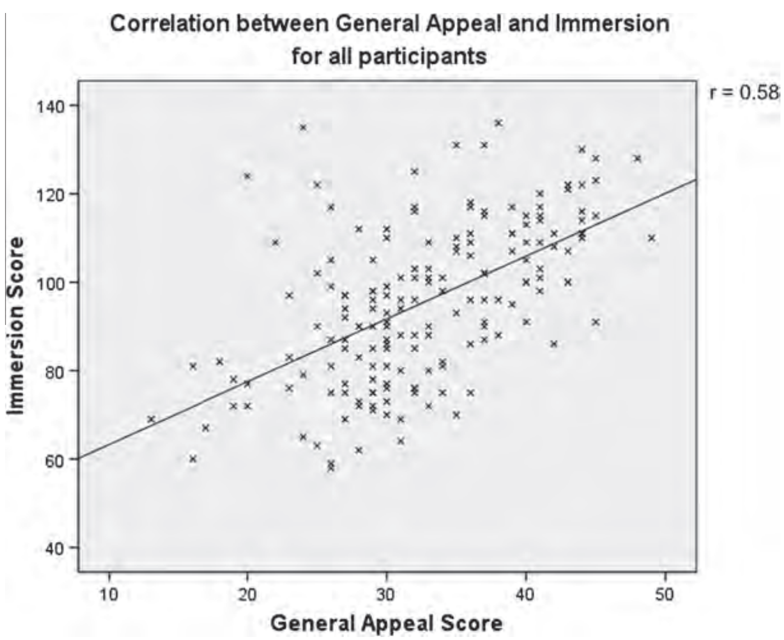

Fig. 4. Graph showing the relation between Immersion and Appeal.

Table 2
Correlation analysis between appeal and immersion by amount of playing experience and game played.

	Inexperienced players	Experienced players
World of Warcraft	$r(36) = 0.52$, $p = 0.001$	$r(44) = 0.43$, $p = 0.003$
Half-Life	$r(49) = 0.54$, $p < 0.001$	$r(36) = 0.65$, $p < 0.001$

The answers to the first two questions come from the MANOVA. The answer to the third question comes from the correlation analysis.

Starting from the third question, the correlation analysis between immersion and appeal shows larger than typical effects for all combinations of player experience and game played, as well as a larger than typical effect for all players that took part in the experiment. This means that appeal and immersion are intimately related. However we cannot deduce anything about the direction of causality between immersion and appeal. What the study does tell us however, is that because appeal and immersion are connected, players who find a game appealing will also find it more immersive, and the opposite: players who find a game immersive, will also find it more appealing.

The MANOVA results tell us that while playing experience impacts how appealing and how immersive a game is found, its impact is only felt if the type of game played is taken into account.

In contrast, the type of game has a significant effect on both immersion and appeal.

To answer the first question, we examine the follow-up univariate ANOVA for immersion. Immersion is not affected by the players' amount of playtime of the game in question (Fig. 3b). This may suggest that immersion is a player trait rather than a game trait, which would corroborate a position found in the Virtual Reality literature (Witmer & Singer, 1998). It also may corroborate the view that immersion is a willing suspension of disbelief as described in Section 1.1, and which is frequently cited as the reason for the occurrence of immersion (i.e. Adams, 2010), but this should be viewed in connection with the relation between immersion and appeal. We discuss this briefly in Section 5.

The second question examines appeal differences in the four groups. We find that there is a simple main effect of game played to appeal for inexperienced players, whereas there is no statistically significant effect found in the case of experienced players (Fig. 3a). This is an expected result, because experienced players of a game will all find the game they have played to completion, or the game they are still playing, appealing. Otherwise, they would not play it until they finished it, or they would not continue playing it in order to reach end-level. This result also tells us that players will decide whether they like a game or not when they first come in contact with it, and this will be reflected in their appeal score. Fig. 3a also suggests that the dated graphics, and maybe even the first-person view, of Half-Life are not appreciated as much as the 3d-person cartoony, significantly more polished graphics of WoW. Therefore inexperienced players find significantly more appealing the more recent game (WoW). Contrary to this, WoW experienced players report lower levels of appeal than the inexperienced players, with the opposite occurring in the comparison of Half-Life players. This is probably due to the difference in the goals of the two games. WoW's goal is retention of its players, and recruiting of more. Half-Life's goal is to draw players to buy the game, and then provide a playing experience consistent with the players' expectations until the game finishes. But playing the same game for a long time inevitably will bore players, even if their appeal levels remain high, leading to a decrease in the appeal that they report compared to when they first played the game.

Considering that a non-statistically significant result cannot (and should not) be interpreted, we still believe that the lack of statistical significance in the difference between the inexperienced and experienced players in terms of appeal is interesting. The lack of difference hints to the supposition that players may initially evaluate a game, and the initial perceived appeal decides their further relationship with the game. This could mean that a good first impression may make up for an otherwise less interesting game as the player moves further into the story and/or gameplay. Therefore, first impression may play a big role in whether players will adopt a game or not. This has obvious repercussions on the initial presentation of a game, where exhibiting features that players find appealing from the beginning may hold them for longer periods of play, something especially important for games that use pay-to-play (i.e. MMORPGs). However, to examine this speculation further, a longitudinal study is necessary that will examine how players' appeal perceptions vary over a period of time.

Hence, the results point to the need for a longitudinal study that would follow the appeal and immersion levels of players from first play session to the players' becoming experienced (either finishing the game or reaching end-game goals). A longitudinal study would also allow us to further examine the causal relationship between immersion and appeal. However, in the next section we speculate on the causality direction based on the evidence gathered from this study.

5. Speculations on the causality direction between immersion and appeal

As mentioned previously, immersion and appeal are intimately connected. Taking together the results of the two analyses we speculate here on the nature of the causality direction of the relation. Taken independently from the other results of the study, the answer to the question of immersion differences between the four groups is that the game played decides the level of immersion of the player (Fig. 3b). This is because there is a significant difference between the immersion levels between the two games, but no significance when examining playing experience. By itself, the result corroborates the predominant popular opinion that certain games are more immersive than others (i.e. Retaux, 2003). But considering the rest of the results, especially the high correlation between appeal and immersion, this view becomes problematic. The reason becomes clear when the correlation results are discussed, further below.

Considering appeal as the cause of immersion, the supposition that games are immersive becomes false. From the findings on appeal, first impression seems to create a level of appeal for each player, which is the substrate upon which the player experiences the rest of the game. If this first impression of appeal is high, then the player should experience a high level of immersion. If it is low, then the player should not become deeply immersed. Since the player's appeal towards the game decides how immersed the player will become, the game cannot be dubbed immersive, but rather appealing. The immersion quality in this case should be attributed to the player and his/her willingness to suspend disbelief to become deeply immersed.

On the other hand, if we consider that immersion leads to appeal, then the player would first have to be immersed in the game, and then find it appealing to continue playing. This would mean that players would need to be patient until they become deeply immersed in a game, implying that there should be different levels of appeal between inexperienced and experienced players of the same game. However, this is not the case, at least in the context of this study. Therefore, we believe that appeal leads to immersion, and as appeal grows, so does the players' willingness to suspend disbelief further and become further immersed in a game.

6. Conclusions

In this article we presented a study performed to examine the differences between the perception of appeal and immersion of experienced and inexperienced players of two widely successful games, WoW and Half-Life. This study also examined the relationship between the perception of appeal and the depth of immersion on the two games.

The results show that the appeal of a game experienced by players who have not played it before depends on the game played. Thus, game content and game type is an important factor to consider in the players' choice of game to play. Immersion was shown to vary with game chosen, and this effect was exhibited over both experienced and inexperienced players. The most important result however, is that a positive correlation was found between immersion and appeal. This means that high appeal for a game leads to high immersion, or vice versa. This effect is larger than typical, and is demonstrated over both amount of play time, and over game played.

The study elucidates a part in the literature that was implicitly included: that appeal is a factor in the gameplay experience, and that it is affected by or affects immersion. Thus, the study provides concrete evidence on the connection between these two attributes of the gameplay experience, thus contributing the further clarification and construction of a theory of gameplay experience.

The study also points towards future work that needs to be done, to elucidate the results and further investigate the relation between immersion and appeal, in the form of a longitudinal study. This is necessary in order to examine how player perceptions of appeal change over time, and correlate those appeal perceptions with corresponding measures of immersion scores. The results of such a study will help us understand the direction of causation between immersion and appeal, leading to concrete game design and development guidelines towards games that will offer more appealing and immersive experiences.

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Becoming nature: effects of embodying a tree in immersive virtual reality on nature relatedness

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The potential of using immersive virtual reality (iVR) technologies to enhance nature relatedness by embodying non-human beings, such as plants or animals, is only sparsely researched. To contribute to this emerging research field we conducted an experimental study (N = 28) that compared the effects of the viewing condition (iVR or desktop) while embodying a tree on nature relatedness, perspective-taking and, as a control, on perceived immersion. A mixed-method approach employing quantitative and qualitative questions was used. Our results showed that irrespective of condition allocation, the more immersed participants felt in their experience, the greater they reported increased levels of nature relatedness ($r = 0.42$, $p < .05$). While our quantitative data did yield a difference in immersion levels between the viewing condition (iVR vs. video, $t(26) = 2.05$, $p = .05$, $d = .50$) that did not translate into a stronger experimental effect of the iVR condition on nature relatedness ($F_{Interaction}(1,26) < 1$). Regarding perspective taking, no significant differences between both groups emerged in the number of users who self-reported having fully taken on the perspective of the tree, ($\chi^2(1) = 2.33$, $p = .127$). However, only participants from the iVR group described their experience from a first-person perspective, suggesting a higher level of identification with the tree. This matches the observation that only those participants also reported self-reflective processes of their own role as a human being towards nature. Our results support previous research suggesting that experiencing nature via immersive VR in itself does not seem to suffice for creating an effect on nature relatedness. However, we observed that a higher perceived level of immersion for participants experiencing the embodiment of a tree in the iVR condition provoked reflective processes on one's own role towards nature more strongly. We discuss the role of immersion and further factors to explain these differences and suggest steps for future research settings to help understand the beneficial potential of using immersive VR for nature relatedness.

One of the most pressing issues of the twenty-first century is to find and implement countermeasures to the ongoing climate crisis and destruction of nature. While technical solutions are being developed at a fast pace, successful implementation depends not only on the availability of technology but on creating an awareness about mechanisms of sustainable development and on transferring this awareness into actual actions on the individual level. Besides efficiency and consistency as promising technology-based strategies, a person's relationship towards nature has been argued to be a predicting factor for sustainability-oriented behaviour within a sufficiency strategy[1]. Thus, it is vital for education for sustainable development that this relationship is nurtured and supported[1,2]. While a cognitive understanding of the impact of one's daily actions on nature is the intellectual base for finding new solutions[2], they will only be implemented if a corresponding motivation is present. The role of other species and natural systems and their importance for the ecosystem have to be understood in order for people to be able to reflect on their relatedness towards nature[1,3]. Thus, it requires methods that address the affective dimension, break through previous habits, and train the ability to act[4,5]. In the concept of Education for Sustainable Development perspective taking is argued as an approach to foster understanding and reflecting one's relationship towards others (cognitive dimension), and by that, relating to it (affective dimension)[6]. Based on the idea of "perspective transformation" by Mezirow[7], the experience of taking on someone else's role, by methods as such as role-play, is discussed as a promising method to reflect on one's own role in climate change, understand one's personal impact on climate change and promote the ability to relate to others[8]. Mayer and Frantz[1] argue that a feeling of connectedness to nature leads to a stronger concern for nature and can invoke action such as

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pro-environmental behaviour. Previous studies have shown that direct exposure to nature can strengthen a feeling of nature connectedness or nature relatedness[1,9–11]. It can also influence environmental knowledge, attitudes, or behaviour[12–15]. In line with environmental psychology[16,17], we define nature as '…a broad category of natural environments and features of those environments, such as single trees or plants' (van den Berg et al.[17], p. 57). This understanding includes images of nature in the form of videos, films, or other imagery.

However, due to urbanization, it has been observed that more people live removed from nature, e.g., natural environments such as forests, and those have a low concern for nature[15]. Today, 82 per cent of the North American population, 81 per cent of the Latin American and the Caribbean population, and 74 per cent of the European population live in urbanized areas. This urbanization trend is predicted to grow from 55 per cent to 68 per cent of the worldwide population by 2050[18], with the result that the accessibility of nature, and thus the ability to experience it in person, is reduced. It then becomes harder to see oneself as part of a natural ecosystem, which in turn may lead to less concern for nature and thus less pro-environmental behaviour. At the same time, traveling to especially highly valuable ecosystems in terms of biodiversity and greenhouse gas capture as e.g., the Amazon, is neither feasible to provide a large number of humans with this kind of experience nor without risk for the local ecosystem. This raises a vital question: How can the processes of reflecting on oneself as part of the natural ecosystem be supported for those without access to natural environments, be it due to urbanization or other restrictions? The positive effects of being exposed to nature are not limited to experiences in real-world nature settings, as Meidenbauer et al.[19] demonstrated. According to their study, even the act of simply looking at an image of nature or virtual environments depicting nature could achieve similar results. However, Zelenski et al.[20] found that exposure to nature via video-watching can promote '…greater willingness to engage in environmentally sustainable behavior' (Ref.[20], p.24). These effects become more pronounced the more users perceive the experience as a real, personal one.

New solutions to provide such real, personal experiences of distant biospheres might be offered by modern immersive virtual reality (VR) technology. Thanks to highly developed technology, virtual sights of nature can be experienced with a 360°-degree angle (e.g., Nature TreksVR). Putting on a Head-Mounted-Display (HMD), users can go beyond simply looking at a landscape in front of them. Instead, users can be completely surrounded by it. Hu-Au and Lee[21] argue that immersive VR technologies offer increasing engagement, provide interactive, action-oriented, affective, and empathetic experiences, and can serve as an 'arena for visualising' (Ref.[21], p.216). Individuals can take on someone else's perspective, close the time gap between action and consequences, get interactively involved, receive direct feedback on decisions and behaviour, see consequences, foresee future climate change scenarios, and experience sensory stimulations that can have a strong impact on affections[22–26]. The assisting role and the success of technological components in creating a convincing and captivating experience can be subsumed under the term "immersion"[27], while the engagement of multiple sensory channels has been coined "sensory immersion"[28]. Both definitions suggest that the perceived presence is influenced by the level of immersion provided by a virtual application, and the technological components used to experience the content. This in turn influences the motivation to transfer what was learned into actions. Immersive VR technologies are defined as technologies that immerse the user as much as possible in the virtual experience, especially via the use of HMDs[29], which allow the users to translate their natural head movements into camera movements within the virtual environment, providing a higher level of immersion compared to watching videos or pictures via a desktop screen[30]. Immersive VR shows promising potential to reduce the gap between virtual representations and real-life experiences, which are vital to fostering behavioural change. Positive effects of VR applications on motivation, knowledge, engagement, task performance, and long-term retention have already been observed in the context of learning[31–35]. Today, immersive VR technology has evolved to a point where users can enter immersive artificial environments via HMD comfortably from their own living rooms[30]. Worldwide, the demand for VR headsets is forecasted to reach USD 62.1 billion by 2027[36]. Side effects such as motion sickness have become more preventable via the appropriate design of the virtual environments or by accustomization[37]. Devices have become affordable, do not necessarily require access to high-end PCs, and can be used with a smartphone (e.g., Google Cardboard, the Oculus Quest, Valve VR, or the HP Reverb G2). This development is a prerequisite for bringing the proverbial mountain to the prophet: It allows researchers to provide the most immersive portal to nature experiences to people who are unable to have these encounters in-person.

However, there are still only limited numbers of virtual nature applications on HMD available, and valid research results for the use of these applications in the various fields of the Sustainable Development Goals (SDGs) are still in the nascent stage[26]. So far, there are only few data on the cognitive, socio-emotional, or behavioural effects of immersive VR technology applied to environmental awareness. Studies on immersive nature experiences in VR have investigated effects on mood[23,38], physical engagement[39], green product consumption[40], interest[26], pro-environmental behaviour[22,25,41], and nature relatedness[41]. In the majority of the studies, participants have been exposed to 360° videos of nature via desktop or HMD. Ahn et al.[22] showed that climate-change-related applications experienced via a HMD '…can be strong enough to transfer into the physical world to modify behaviour' (Ref.[22], p. 85). Filter et al.[26] let students experience 360° videos about the life of wolves via HMD, showing that immersive technology can foster interest in nature experiences. Klein and Hilbig[25] exposed participants to nature videos of trees or birds and compared it to conditions of watching videos about social interactions or urban environments. The authors observed that watching videos of nature destruction can have a stronger impact on pro-environmental behaviour compared to experiencing a video about actual intact nature. Soliman et al.[41] investigated effects of artificial nature videos vs. real nature videos on nature relatedness and pro-environmental behaviour. As one of the results, the authors observed that watching videos of nature can foster nature connectedness irrespective of the technology used (immersive VR vs. desktop screen). Mostarejan et al.[38] showed that watching 360° videos of a forest via HMD has a stronger effect on mood compared to looking at pictures of a forest using HMD.

The beneficial effects of immersive VR on inter-human relationships and cognition seem to be reproducible for the interaction with the impersonal 'other', such as nature. Immersive VR, with its typical display mode of exploring experiences from a first-person perspective, facilitates taking on the perspective from which the experience was filmed or created. This allows the experience of embodying the portrayed agent. This is a prerequisite for the learning transfer of applications set in the context of sustainable development. Seeing the potential of what effect the mere visual experience of virtual representations of nature can have on nature relatedness, a more immersive experience such as embodiment of nature could increase the impact even further. Available VR applications can include experiences that play with what it means to see the world from another's eyes. Experiences such as 'The Machine To be Another' from AnotherLab have provided insights into how swapping perspectives and embodying another person can be used to train empathy[42]. The beneficial effects can far surpass momentary affections: By swapping perspectives with that of female victims of domestic abuse, male offenders have not only reported increased levels of empathy towards victims but experienced the long-lasting effect of being able to better judge the emotions of others[43]. While the potential of embodiment, body-swapping, or body-ownership of a human in VR has been examined in various research contexts, research on non-human embodiment such as embodiment of an animal, a robot, or a plant is still in its early stages[44–47]. Ventre-Dominey and colleagues[46] have examined the effects of embodying a robot on its acceptability. The authors observed that taking on the perspective of a robot can increase its likability as long as one´s own body movements match the movements of the robot in VR. Oyanagi and Ohmura[47] focused on the effect of embodying a bird on anxiety about heights. The authors could report a decrease in self-reported fear of heights. As of now, to our knowledge, there are only two studies that focus on embodiment and its effects in the context of nature relatedness[44,45]. Markowitz et al.[45] conducted a study comparing non-human embodiment (a coral) and human embodiment (a scuba diver) stating that '…the more that people reported being attuned to the virtual environment in the post-test, the more they learned in immersive VR, felt connected to nature, and reported environmental concern' (Ref.[45], p. 10). In several experiments by Ahn and colleagues[44], effects on nature connectedness by being a coral and a cow were measured by comparing the VR experience via HMD to watching a desktop video. The authors observed that embodiment of a virtual other, was crucial for a high degree of connectivity to nature. They argue that embodiment in VR can foster especially the potential of perspective taking.

In our study, we transfer and expand the ongoing embodiment research to non-human and non-animal agents, and systematically compare the effects of embodying a tree between a standard viewing condition and an immersive VR (iVR) condition that displays the experience with a HMD and features the option to make small branch movements via controllers on nature relatedness. While perspective taking in itself is associated with favourable attitudes, the immersion via HMD in a virtual environment has been shown to be the determining factor of the occurrence of attitude change[48]. Therefore, a combination of perspective taking supported by embodiment through iVR is a promising approach to explore the transfer to a non-human, non-sentient entity in the context of climate change and nature relatedness. Thus, the aim of our study was to investigate whether experiencing the embodiment of a tree via iVR fosters a) a feeling of immersion, b) relatedness with nature, c) perspective-taking, and d) reflection on the relationship between humankind and nature. Taken this under consideration, we understand our study as continuing the conversation on how embodiment in VR technology can foster nature relatedness.

We carried out an experimental study with 28 participants in a $2\times2\times2$ between-subjects design with *condition* (iVR vs. video watching) and *ending* (negative vs. positive) as between-subject factors and *time* (pre-post measurements) as a within-subject factor. Both experiencing conditions differed as follows: the iVR experience allowed for free head movement, creating the ability to look around freely. Additionally, hand-held controllers translated the users' arm movements into a slight movement of the tree's branches. The video desktop screen condition displayed a fixed orientation of the view and did not include the interactive element of branch movement. This decision was made based on the technical limitations of making the experience which has been developed for iVR accessible via desktop screen.

Three dependent variables (perceived immersion, nature relatedness, perspective-taking) were measured with a questionnaire that asked additional open questions to tackle further reflections on the experience of embodiment. Participants were randomly assigned to one of four conditions (iVR vs. video watching; positive vs. negative ending). As positive vs. negative endings were not of focal interest and did not yield different results, we report hypotheses and results for the factor experience condition only. Thus, the following hypotheses were tested:

- H1: Experiencing the embodiment of a tree via iVR is perceived as more immersive than watching the experience as a video on a desktop screen.
- H2: Experiencing the embodiment of a tree via iVR leads to higher levels of nature relatedness than watching the experience as a video on a desktop screen.
- H2b: Perceived immersion levels are associated with an increase in nature relatedness.
- H3: Experiencing the embodiment of a tree via iVR facilitates more perspective-taking of the tree compared to watching the experience as a video on a desktop screen.

We were also interested in exploring the subjective experience of participants concerning the reflection of their own relationship with the tree, assuming that the experience of embodiment of the tree in iVR initiates a stronger process of self-reflection than when watching a video of the same experience as a video on a desktop screen (H4). We therefore added open questions, described in measures. By the explorative combination of qualitative and quantitative data, we hope to enrich the discussion about the effects on embodiment in iVR as a tool to foster perspective-taking as one relevant goal of education for sustainable development by means of reflecting on the role of other living beings on this planet[2,6–8].

Figure 1. View from the perspective of the tree during the forest fire (to the left) and during daylight (to the right).

Materials

The application 'Tree', available for HTV Vive, was used as stimulus material. 'Tree' has been conceptualized and realized by a group of designers and researchers at MIT in collaboration with film directors[49]. The application used has been screened as a film at over more than 60 festivals worldwide and won multiple awards (https://www.treeofficial.com/). Using a head-mounted-display, the user takes on the view of a tree in the Amazon rainforest. The user experiences the birth of a tree and its life in a fixed chronological order. The growth is portrayed, first underneath the earth at the beginning, then up until the final height of the tree. This experience is displayed from a first-person point of view, giving the impression of being the tree. Upon reaching the full height, night falls. A fire starts in the far distance, accompanied by drum sounds. The fire approaches and neighbouring trees catch on fire. Right before the portrayed tree catches on fire, too, the perspective shifts to a third-person view of the tree and the experience ends. Two adaptations were made to the material: First, a second version with a positive ending was created by having the original experience which lasts for 6:48 min, stop at the 4:40-min mark upon nightfall, omitting the forest fire. Second, to make the experience available as a video watching condition, a screen recording of the iVR experience was created for both the positive and the negative ending (see Fig. 1).

To develop the video version of the tree's experience, we recorded a game play of a volunteer in iVR via HMD prior our experiment including turning the head movements for close-up views of targeted objects (e.g., birds, monkeys). The course and content of the experience was identical in both experiencing conditions, and participants experienced the application either in 4:40 min (not including forest fire) or in 6:48 min (including forest fire) in one of the viewing conditions (iVR or video watching). Also, in both conditions, a background sound of animals in the Amazon was audible as part of the soundscape of the application using the same sort of headphones. The difference between conditions in our experiment was that in iVR, participants were able to slightly move the tree's branches via controllers. We understand this movement as extending part of the embodiment experience in iVR via HMD. Thus, the conditions were completely comparable with exception of the ability, when used, to move the branches and to freely look around in 360 degrees during the fixed course of events (birth, life, and end).

Methods

Participants.

28 students participated in the study (14 = male; 14 = female). Participants were between 22 and 35 years old (M = 26.32; SD = 3.1). The participants volunteered to be part of the research project and were not compensated for their participation. The study was carried out in accordance with the guidelines of the German Psychological Society provided as self-assessment-tool by the Ethics Committee of the Department of Psychology and Ergonomics of Technical University of Berlin in accordance with the Declaration of Helsinki (2013) with written informed consent from all subjects. Participants of the study were informed about the content of the experiment, possible adverse effects of exposure to the virtual reality application, the anonymization procedure, and data usage. Participants were informed about the voluntary nature of the study and were told that they were able to withdraw from the experiment at any point without need to state any reason and without any consequences. Furthermore, before the study, participants were asked about prior experiences with motion sickness, and if they had experienced motion sickness, explicitly asked to verify their participation. They could request the deletion of their data within 7 days of their participation.

Procedure.

Participants were randomly assigned to one of the conditions (iVR or video watching on a desktop screen and positive or negative ending). Each participant was greeted by the assigned experiment conductor. Participants were then asked to read a short description about the experiment and signed the consent form. Afterwards, they were asked to fill out our pre-test questionnaire. If selected for the video watching condition, participants started to watch the experience via video on a desktop screen. If selected for the iVR condition, participants were guided to the middle of the VR tracking area and received controllers and headphones (see Fig. 2). In the iVR condition, participants started in the so-called 'credits room' of the Tree application to get used to the visuals and the VR environment. After that, the actual Tree experience was started. After the experiment, in both experimental conditions, participants completed the post-test questionnaires containing quantitative

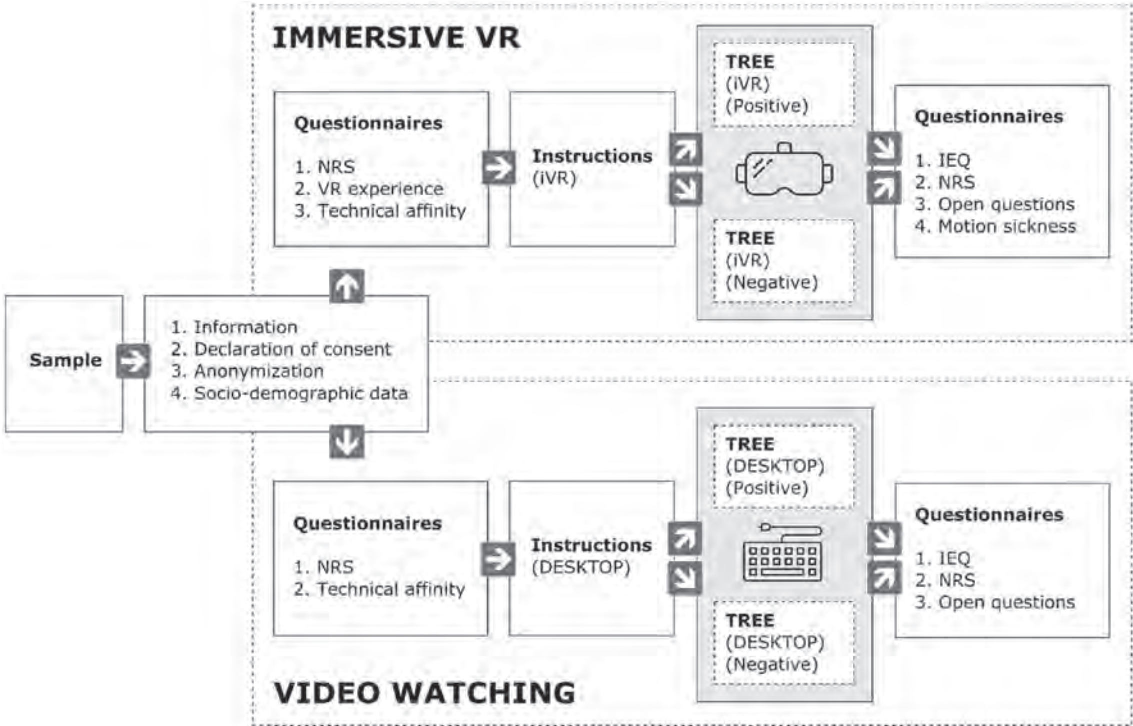

Figure 2. Experimental procedure for the conditions. Own illustration, adapted from final report of students[50]. IEQ = Immersion Experience Questionnaire; NRS = Nature Relatedness Scale.

and qualitative questions to describe their experience during the experiment in detail. Comments or difficulties during the experiment were documented by the experimenters.

Technical equipment. For the immersive VR condition, an HTC-Vive (MV HTC LHR-7433AF4C) including HTC-Vive controllers (MV HTC LHR-FFA61F42 & MV HTC LHR-FF663B42) was used as a means of display and interaction, respectively. The sound output was transferred via on-ear headphones in both conditions. A desktop PC with Windows 10 and a 24-inch monitor (NVIDA GeForce GTX 1060) with a resolution of 1920 × 1080 pixels was used for the video watching condition.

Measures. The following scales and questions were used within the study:

Socio-demographic data. The questionnaire contained items on socio-demographic data such as age, gender, prior experience with VR applications (one item, 'Do you have any previous experience with VR?'), and technical affinity (one item, 'How interested are you in using electronic devices such as computers, tablets?').

Perceived immersion. The Immersive Experience Questionnaire (IEQ) has been classified as a valid instrument to measure immersion in digital games[51–56]. The IEQ aims to assess the notion of immersion and defines immersion as a concept that contains five factors (cognitive involvement, emotional involvement, real world dissociation, challenge, and control). This classification is in line with the definition of immersion and immersive VR by Slater[30] and Kim and Biocca[28] which we employ. The short scale contains 18 items (5-point Likert scale from 1 = I strongly disagree to 5 = I strongly agree, e.g., 'I had the feeling of being separated from the real world'; Bentler's Omega $\Omega = 0.80$; 3 items reverse-scored). To our knowledge, there is no validated German version, thus, the questionnaire was translated into German.

Nature relatedness. The extent to which people feel related to nature was measured with the Nature Relatedness Scale (NRS). The NRS contains affective, cognitive, and experiential items asking about one's relation to nature[10]. The German version[57] of the Nature Relatedness Scale- (NR-6) by Nisbet and Zelenski[58] contains 6 items (5-point Likert scale from 1 = I strongly disagree to 5 = I strongly agree, Bentler's Omega $\Omega = 0.78_{pre}/0.85_{post}$). The NR-6 is based on a longer version of the NRS with 21 items[9], and the NR-6 (hereafter referred to as the NRS) correlates strongly with the longer version[58] (Bentler's Omega $\Omega = 0.78$).

Perspective-taking. To explore a deeper understanding of the embodiment experience of the tree, participants were presented four open questions, a) how did you like the application Tree? B) could you take on the perspective of the tree, and if not, please specify your experience, c) did you notice the presence of any other animals

	Condition	Pre		Post		
	iVR versus video watching	M	SD	M	SD	n
Immersive experience (IEQ)	iVR			3.35	0.53	14
	Video watching			2.97	0.45	14
Nature relatedness (NRS)	iVR	3.12	0.64	3.17	0.82	14
	Video watching	3.30	0.83	3.45	0.85	14

Table 1. Descriptive statistics for immersive experience and nature relatedness, pre- and post-experiment. 1 = 5-point Likert scale (1 = strongly disagree to 5 = I strongly agree).

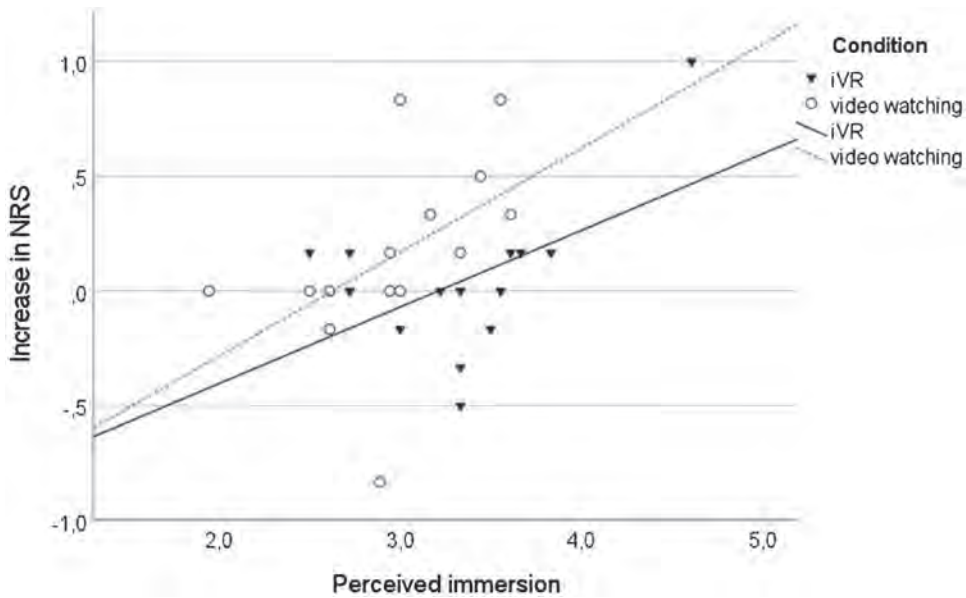

Figure 3. Correlation of perceived immersion and increase in nature relatedness. *Note*: Data points correspond to scale means (perceived immersion) and post–pre delta values of scale means (increase in nature relatedness) for each participant.

in the application, d) did the experience evoke any emotions in you? If yes, please describe them in your own words.

Motion sickness. Participants assigned to the iVR group were controlled for motion sickness using the Virtual Reality Sickness Questionnaire (VRSQ) by Kim et al.[59] containing 9 items. The items describe different symptoms (e.g., headache, tiredness) to be rated on the strength of their occurrence during the experience (1 = not at all to 4 = strong).

Results

Effects on perceived immersion (Hypothesis 1). A t-test for independent samples ($t(26) = 2.05$, $p = 0.05$, $d = 0.50$) revealed that participants who experienced the embodiment of a tree in iVR perceived the experience as more immersive (M = 3.35, SD = 0.53) than those who were watching a video on a desktop screen (M = 2.97, SD = 0.62).

Effects on nature relatedness (Hypothesis 2). A two-factorial ANOVA for nature relatedness revealed neither a main effect of time ($F(1, 26) = 1.95$, $p = 0.18$) nor of condition ($F(1,26) < 1$). Presented in Table 1, the descriptive statistics reveal that neither group increased their nature relatedness substantially, and the expected stronger effect for the iVR group was also not observed, as indicated by the lack of interaction between time and condition ($F(1,26) < 1$).

Relation of perceived immersion and nature relatedness increase (Hypothesis 2b). To further explore the role of immersion in strengthening nature relatedness, we ran a correlation analysis of the scale means of reported immersion and the delta values of post–pre measures for the nature relatedness of each participant. A significant association ($r = 0.42$, $p = 0.034$) was found as presented in Fig. 3. This means that irrespective of their condition allocation, the more immersed people felt in their embodiment experience, the greater was their increase in nature relatedness.

Effects on perspective-taking (Hypothesis 3). 10 out of 14 of participants (71%) in the iVR condition felt they were taking on the tree's perspective, compared to 6 out of 14 participants (42%) in the video watching condition. This distribution did not differ significantly from an equal distribution ($\chi 2(1) = 2.33$, $p = 0.127$).

Taken together, our quantitative results show that a) while on average the iVR group felt more immersed (see H1), b) the video watching group showed a stronger nature relatedness increase per immersion unit (higher slope) and c) across all participants, there was a medium-sized correlation between perceived immersion and increase in nature relatedness (see H2b).

Qualitative results. *Exploration on reflective processes.* Participants who could not take on the tree's perspective mostly mentioned reasons such as the '*movements of the tree didn't feel natural or real*' (4x), followed by individual reasons such as '*the tree itself did not make any sound*' (1x), '*animation was not real enough*' (1x), '*I could not see the tree's trunk*' (1x), '*a tree perspective was too abstract to me*' (1x), '*the zoom-in function was too confusing*' (1x), and, '*the desktop screen was too small*' (1x). The response to the open question of how the Tree application was perceived showed that 24 out of 26 participants reported a very a positive impression of the application, described in terms such as '*fascinating*' (2x), '*exciting*' (3x), '*powerful*' (1x), '*beautiful*' (3x), '*very interesting*' (7x), and '*great*' (3x). At the same time, participants described in detail how their impressions were perceived. For instance, one participant in the iVR condition perceived the application as fascinating because he/she '*felt affected by the fate of the tree*'. Other participants (desktop condition) described the experience as beautiful because they felt a sense of '*cosiness*' and '*security*' as well as '*a feeling of wanting to protect nature*'. Two participants reported no feelings at all besides being amused and astonished that '*The tree grew damn fast within one day*' (desktop condition). Another participant also referred to the fast growth of the tree as they reported that they '*felt nothing but curiosity*' (iVR condition). Answering the question how the experience was generally perceived, especially participants of the iVR condition also indicated experiencing an elevated sense of presence while in VR. For instance, participants reported '*Great. The growth of the tree and the exploration possibilities are impressive, and you have the feeling of being there completely*', and '*I thought it was great, it's crazy how close to reality it is. You really have a little bit of the feeling of really being there*', as well as '*I felt like I was in the rainforest*'. Two participants indicated a perspective change by reporting their experience out of the tree's perspective, using first person pronouns: '*My body became taller and taller*', and '*I am part of the forest and also have a great role in nature as a tree.*'

Answering the qualitative question about which emotions, if any, were involved (n = 27), eight participants described feelings of relaxation (5 × video, 3 × iVR), four participants reported feelings of concern or stress (2 × video, 2 × iVR), and five participants reported sadness (2 × video, 3 × iVR) which was equally distributed between the positive and negative endings. While five participants of the iVR condition (4 × negative ending, 1 × positive ending) explicitly reported a self-reflection of their own role as a human being towards nature such as '*You immediately dealt with it in your head and recognized the beauty of nature. I feel a little bad now that we humans are destroying nature like this*', and '*At first, I felt excitement and curiosity. Then wanderlust at the starry sky, followed by consternation at the start of the fire, and then, the feeling that we as a society are to blame for it*'. Another participant said he/she felt '*Sadness about what fires, partly caused by humans, cause, and especially with regard to the current situation in the Amazon, shocked*'. The answers to the open question 'Which animals were noticed during the experience' varied in content, but participants over all conditions reported that they had perceived a variety of animals, such as birds, a tiger, a monkey, insects, or butterflies.

Further results. Overall, participants of the sample were very interested in technical devices (M = 4.61, SD = 0.57), and 22 participants of the sample (78.57%, N = 28) already had experience in immersive VR using HMD applications. On average, participants would recommend the application to others (M = 6.5, SD = 2.68). Participants reported almost no signs of motion sickness (M = 1.37, SD = 0.23).

Discussion

Our study provided results that are partly in line with previous studies regarding embodiment and nature relatedness in immersive VR. Firstly, the embodiment experience of a tree via iVR is perceived as more immersive compared to watching it as a video on a desktop screen (H1). Against our presumptions, the embodiment experience fosters nature relatedness neither generally nor respective of condition allocation (H2). Crucial for a rise in nature relatedness seemed to be the perceived feeling of immersion (H2b) and not the viewing condition (iVR vs. video) per se. These results are in line with Soliman et al.[41]. Although Soliman et al. compared watching videos via HMD and desktop screen, the authors also observed that immersive VR technology itself does not automatically lead to higher nature relatedness. It can be assumed that immersive VR technologies are not yet at the ultimate level of what is technically possible, and some technical issues come with their use that some features (e.g., bucking, lighting conditions, individual expectations) might counteract immersion. Ruling out technological aspects, individual differences in expectations towards the iVR technology as well as the individual readiness to immerse are likely to affect the outcome and, while not accounted for in this study, should be further investigated in future experiments. As Ahn et al.[22,44] and Ventre-Dominey et al.[46] point out, interactivity and movements of the person's own body resembling the virtual body play a significant role in fostering perceived embodiment, and in the case of nature connectedness or nature relatedness, might be more relevant than perceived presence[44]. Furthermore, our quantitative data did not support the hypothesis that embodiment of the tree via iVR facilitated perspective-taking (H3). As no differences between conditions emerged, technological immersion factors can be regarded as playing a secondary role in explaining the readiness to take on the embodied perspective, suggesting that an investigation of personality traits and individual factors might be worthwhile.

Contrary to the quantitative results, the qualitative data suggest that embodiment of nature can be a beneficial approach to initiate a reflective process on the role of other species as part of our eco-system. Participants reported a high amount of perceived realism, of presence, and felt an impact on their emotional state, such as subjective feelings of connectedness with nature, in line with previous research[22–25]. Only those participants in the iVR condition self-reported reflecting on the relationship between humankind and nature, as indicated by statements referring to their impact as a human on the tree's fate or on themselves as being the tree. The reported subjective data shows how the experience of being one single tree can transcend the individual level and evoke reflective processes on a more universal level, relating to the distant biosphere of the Amazon rainforest and nature as a whole. The selection of the distant and unfamiliar setting of the biosphere in the Amazon was intended to reflect the unfamiliarity of a future target group for such interventions with the ecological environment they are supposed to experience. We assumed that most, if not all, of our participants have not experienced such a setting in person, allowing us to exclude a familiarity bias as much as possible. However, we did not address the familiarity with the environment separately, which is something to be added in future studies.

In our study, there were some limiting factors to taking on the perspective of another species. 29% of participants in the iVR condition and 58% in the video watching condition reported not having taken on the perspective of the tree (a total of 43%). The question of why perspective-taking did not happen in these cases remains open. Technical conditions in both experimental groups might have contributed to the limited perspective-taking. Qualitative answers clearly showed that features of the display method were decisive in whether or not a person made the leap into the tree's perspective (e.g., '*the screen is too small*'). Between conditions, however, not only did the display technology differ, but also the extent to which participants were able to explore the virtual environment. The resemblance to the own body was provided by giving the participants in the iVR condition the opportunity to slightly move the virtual branches with the handheld controllers, creating an analogy to their real arms. This amount of movement was small and seemed to not have sufficed to impact the amount of perceived immersion between both groups in a significant way. However, the qualitative data suggests a higher rate of perspective-taking in the iVR group, indicated by statements such as '*My body became taller and taller*', to which the higher number of immersive features might have contributed. Users typically watch videos without further means of interaction, and without an option to choose different orientations of views. Users with access to an HMD do experience a higher level of possible interactivity. In regard to the question of how we can transport the experience of nature to those who do not have access, any findings that show a difference between those conditions would illuminate whether 'traditional' experiences via video are enough to provoke reflective processes, or whether additional levels of immersion are needed and additional costs are justified. Adding more components that address more senses such as touch or smell could create an even more immersive experience that might be able to increase a full-sense immersion via immersive VR technology. This is especially vital in regard to the implementation and widespread distribution of such experiences – what equipment needs to be provided? In future studies, it would be of interest to enhance the levels of possible interaction and sensory channels, and systematically vary them in order to isolate the role of interactivity and also the role of the direct translation of one's own body movements to the virtual self.

Furthermore, taking on the tree's perspective in immersive VR might have depended on the individual's tendency for immersion[60]. Another factor might be the discrepancy between the person's own body and the body of the embodied agent, as Ahn et al.[44] pointed out. In their experiment, participants inherited the virtual body of a cow to foster interconnectedness with nature. The authors state that '…it is important that the individual feels that he or she actually owns the body of the animal.' (p.411). The fact that users had to embody a tree, might have been difficult because a tree's body differs from the human body. Against this background it might have been challenging to create a feeling of body ownership regarding the tree. A further factor on influencing perspective-taking can be individual's prior VR experience. 78% of participants had already used an iVR HMD prior to our experiment. Thus, the acquired results reflect the experiences of the content itself, rather than the experience of the new technology. For instance, the expectations for graphic illustrations and visualizations may have been higher compared to users with less experience in the use of technical devices and VR specifically, including statements such as 'animation was not real enough' or 'my body movements did not match the movements of the tree'. In the context of perspective-taking, it would also be of interest to compare different agents that participants have to embody. For instance, in a previous study, Markowitz et al.[45] compared being a coral with being a scuba diver in immersive VR regarding its effects on nature connectedness, but found no significant differences. To our knowledge, this is the only study of this kind comparing two different embodiment conditions. Following this, in future experiments, additional points of view concerning the tree's fate could be considered to examine its effects on nature relatedness, such as a bystander's perspective, a third person's view, or another person's view, e.g., a fire fighter. The questions of which entity should be embodied and how much interaction the embodiment experience should provide could be explored in future experiments.

Despite the short amount of time spent engaging with the virtual experience, participants of both conditions described a wide range of experiences, with some participants expressing fascination or deep concern for nature. However, the quantitative results reflect this limited exposure: the expected overall effect sizes were small. Thus, to gain a deeper understanding of the individual experiences, we reported qualitative data which yielded further insights. We did not account for the subjective readiness to immerse into the experience in this study, which should be addressed in further studies. Due to the low number of participants ($n = 28$), the experiment should also be replicated again with a larger samples size to have enough power to detect differences in nature relatedness and perspective-taking. An investigation of the optimal duration of embodiment applications would also be helpful to maximize the impact while keeping the time investment for each potential user at a minimum.

Regarding our measurements, future studies should include different questionnaires to examine the relationship towards nature, because quantitative and qualitative answers were inconclusive with the tools we used. Furthermore, the ad hoc translation of the IEQ scale into German has not been validated by a back translation into the original English. This might have reduced the validity of items and should be addressed in a further study. Additionally assessing physiological data in relation to the experience would provide valuable insights into the users' experience at each point during exposure to the application, further pinpointing scenes of interest and disruption. Indicators of stress levels, such as body temperature, heartbeat, or cortisol measures before and after the application, and gaze data over the whole duration could further support the understanding of the impact of experiencing the embodiment of a representative of a non-human species. Furthermore, we focused on assessing users' rating on short term effects by taking measurements right before and after the intervention. Further research projects should focus on long-term changes in concern for the environment as well as on behavioural indicators of these effects resulting in action. It also has been argued for a stronger focus on belief systems instead of emotions when investigating the relationship towards nature[45]. Recording potential changes in behaviour over a longer period after the experience had ended was not within the scope of the experiment. However, Rieckmann[6] and Qablan[8] argue, reflective processes can promote later action-oriented behaviour towards climate protection. Such processes were reported by participants of the iVR condition within qualitative data, but not within the video watching group, suggesting a higher potential for embodiment via immersive VR. Finally, in our study, embodiment was understood as a given feature set by the immersive VR technology via HMD. In future studies, it might be of interest to measure self-perception of the embodiment experience using a reliable scale. An appropriate choice would be a scale developed by Slater et al.[61] to measure embodiment of another human. This scale has already been adapted to the case of virtual animal embodiment by Ahn et al.[44] and could be adapted for applying it to embodiment of a tree.

In sum, our results contribute to the discussion of how embodiment in immersive VR can be extended to other species, even those perceived as non-sentient. We hope to provide further ideas for examining the role of perspective-taking in fostering nature relatedness with the help of immersive VR. Based on our findings, immersive VR and videos alike can provide personal experiences of nature from a first-person perspective for humans who lack easy access to such settings in the real world. Embodiment has been shown to be a promising tool of taking on someone else's perspective. Our results suggest that the majority of users are able to take on a perspective of a tree, an organism not usually considered from a first-person point of view. However, we could show that not all users took on the perspective easily, and, in line with Ahn et al.[44], immersive VR technology in itself might not be enough to promote nature relatedness without taking individual factors into account.

In conclusion, we state that HMDs play a central role in immersive VR technology by allowing for a natural viewing experience of a digital environment. However, besides psychological components, other components that would address additional senses, such as touch or smell, might further enhance the experience and make it even more natural[23]. Additional components of immersive VR that address different senses are still in their infancy, though. Maximizing the technological support for creating immersion, supporting the mental transition into another, non-human being is one of the challenges on the road to creating impactful experiences that lead to nature relatedness, and, by that to behavioural change[1]. The access to such technology is another limiting factor, posing the challenge of finding a balance between technological accessibility and immersive technology. Nevertheless, features such as translating head movements into the positioning and rotation of the camera are already easily supported by low-cost solutions for smartphones, such as Google Cardboard and similar products, opening a large market for immersive educational applications. The experiment could demonstrate that even short applications are able to impact participants. Further research is needed to explore the optimal duration and design of similar applications in order to provoke self-reflective processes and ultimately, nature relatedness. Once the details of optimization are clear, the potential of bringing people all around the globe closer to nature, closer to becoming nature by taking on the perspective of one of its agents in a playful and entertaining manner, can be harnessed to support one of the key components in combatting climate change—human understanding and behaviour.

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Author contributions
P.S. was responsible for concept and design of the work, the interpretation of data as well as the first draft. S.-C.F. contributed substantively to the interpretation of the data, the theoretical background and the revision of the first drafts. S.M.G. has analyzed the data and substantively revised the first drafts. The acquisition of the original data has been done within an official students' project as assignment conceptualized by P.S. The contribution of the students is acknowledged in the acknowledgment section.

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Additional information
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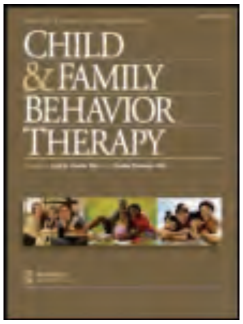

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BRIEFLY NOTED

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BRIEFLY NOTED

FINITE AND INFINITE GAMES: A VISION OF LIFE AS PLAY AND POSSIBILITY. James P. Carse. *New York: Ballantine Books, 1986, 180 pp. $6.99.*

Typically, books for review are suggested by the Editor. In this case this little paperback was suggested recently by an Episcopal Priest, a member of my sailboat racing crew. The reasons for reviewing a 1986 text in 2004 will shortly be made apparent. While originally recommended to be read for personal pleasure, this book turns out to be one of the most profound cognitive psychology treatises I have come across. Written by James Carse, a Professor of Religion at New York University, he has authored a number of books and has received the Universities Great Teacher Award.

As we know, the current in Zeitgeist in Behavior Therapy is to publish books based on empirically supported treatments. This, to some extent, has added to the growing rift between practitioners and researchers in the Mental Health domain. It may be that one reason for this rift is the reluctance of author's focusing on empirically supported treatments to deal with the philosophical basis of much of what is now known as "modern" cognitive behavior therapy. Prior to the PsyD, most psychologists held a degree of Doctor of Philosophy, reflecting psychology's roots in philosophy, which is far from data based. Many of the problems presented by patients are not of discrete disorders. Rather, they represent existential dilemmas and revolve around questions of worth and the meaning of being and when we speak to patients about worth we are not dealing with an empirically supported concept. Notions of worth and equality are philosophical and intrinsically unprovable. When we guide patients belief alternatives and compare the affective and behavioral components which follow from demand-based verses acceptance-based logic we are again entering the realm of philosophy and persuasion for which there can be little or no "proof." There are few books within the behavioral tradition where

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the philosophy of treatment is addressed at all. Thus drawing attention to this book and adding it to your library might begin to help rectify the situation.

Carse's book is divided into seven sections. Within each section, there are numerous brief chapters from one half to two or three pages in length. Each chapter contains impressive thought-provoking content which far exceeds the chapter's brevity, using compelling logic and exact language, each chapter ending with a terse, but profound sentence. The reader is then obliged to ponder Carse's presentation, thinking for extended periods of time after reading a deceptively brief section.

Carse, a master of presenting concise and logical discourse, begins each section with a definition of his terms. It took me some time to put aside any tendency to quibble with his terms. However, once I was able to accept his definitions without opposition, I was able to more fully enjoy the profundity of his discourse. Carse uses the metaphor of games and play to make his points, stating that there are only two types of play, finite and infinite. These terms mirror demand-based verses acceptance-based ideational systems within CBT. Finite play, or demand-based conceptualization, leads to anger, rigidity, myopia, deprecation and the need to "win" as a base for proving one's own self worth and acceptance. Infinite play, or acceptance-based conceptualization, leads to having no need to prove one's worth due to acceptance of this as a given and therefore, having no need to control and/or vanquish others. As we know, behind every bully there is a self-image which is lacking and in pain.

As stated, this is not an easy book to read, short on the outside but of depth and breadth in content. The chapters are purposefully short in that it takes the reader some time to grasp, process, and appreciate what unfolds as one reads. If you appreciate profound understanding coupled with a dramatic capacity to describe succinctly and present a philosophical argument, I do strongly suggest that you read this book. Carse is not a psychologist, yet, this book is remarkably "psychological," taking the essence of cognitive therapy and applying it to the myriad existential areas that therapists constantly face within a treatment context that is so seldom addressed within most CBT texts. If there are courses within behaviorally oriented graduate psychology training institutions dealing with the philosophy of therapy or wishing to address the existential base of much of what goes on inside psychotherapy more fully, this book would be a valuable addition to the reading list. To those willing to allocate a little extra time, this book will provide many stimulating hours which will, hopefully, put a smile on your face and provide you with an unusual intellectual challenge. Compared to other professional texts, its 1986 price of $6.99 is still an amazing bargain. If cost were based on intellectual weight it would be a 100 times more.

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Literature

1. *What's wrong with virtual trees? Restoring from stress in a mediated environment*
2. *What can Play: The Potential of Non-Human Players* (Stone, 2019)
3. *The interplay between immersion and appeal in video games* (Christou, 2014)
4. *Becoming nature: effects of embodying a tree in immersive virtual reality on nature relatedness* (Spangenberger et al., 2022)
5. *FINITE AND INFINITE GAMES: A VISION OF LIFE AS PLAY AND POSSIBILITY* (Paul, 2005)

Case Studies

Electroplankton

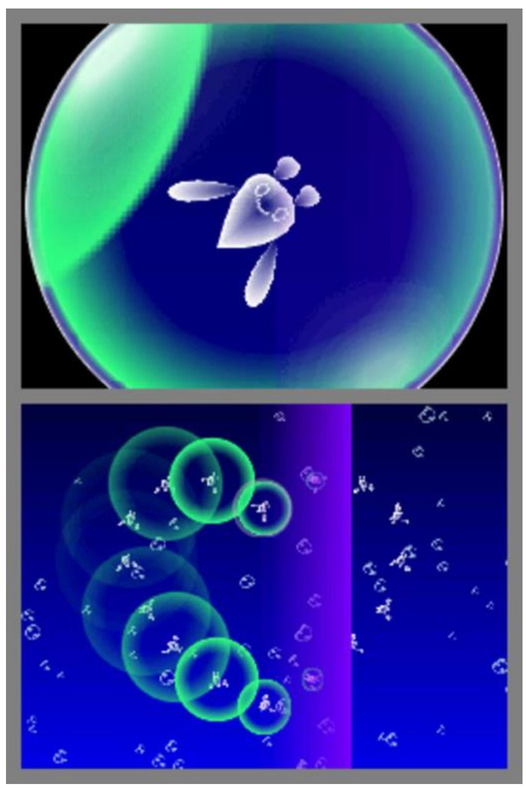

Figure 17 - https://www.cbsnews.com/pictures/electroplankton/

Electroplankton was created by Japanese media artist Toshio Iwai for the Nintendo DS in 2005. I found this case study while looking for video games that use audio as its core mechanic. It straddles the line between interactive media and video game with its unique combination of environmental themes and immersive audio-visual experience. Iwai's design has players interacting with different species of plankton, each producing their own sound behavior. These plankton form together on screen to create a collage of naturalistic digital sounds.

The environment for play is an aquatic landscape, and each plankton responds to the player's input of touch or voice. The interface itself encourages experimentation and can itself be seen as an instrument. While searching for examples online, I found many musicians using multiple Nintendo DS game systems with the game installed to create a soundscape.

As mentioned earlier, I use it as a case study for its use of audio. I wanted to include an example here of game that doesn't contain a soundtrack and instead relies completely on objects to create the sounds of the game. The sound design emphasizes user agency and feedback to a user that could provide useful in environment centered game play.

Death Stranding

Figure 18 - https://gamerant.com/death-stranding-walking-gameplay-immersion-experience/

Death Stranding was created by Kojima Productions, guided by star game designer Hideo Kojima. It was released in 2019 and has a sequel to be released in 2025. This game is known famously as a walking simulator, a game format that has its fans and haters. Walking simulator games have mostly been ignored by the public, however, with Kojima's large fanbase, it became hard to ignore because of *Death Stranding*.

The player is a delivery person in a post-apocalyptic United States, facing the challenge of terrain and supernatural phenomena. I bring this here to focus on the walking and delivery aspect. *Death Stranding* simulates harsh environmental conditions and uses the environment itself as antagonist. The player must use specific button combos to help the character maintain their balance as they traverse the difficult landscape. This is the entire game (minus narrative sequences in-between deliveries).

Death Stranding challenges the player to consider how different route conditions might affect the journey. One may be rocky and require climbing whereas the other might be wet and slippery. It common for the player to fall over, get blown away, and damage the boxes out for delivery. *Death Stranding* centers the digital environment as game character and literally immerses the player into it beyond being a pretty backdrop.

Mountain

Figure 19 - https://www.giantbomb.com/articles/the-madness-of-david-oreillys-mountain/1100-4956/

Mountain was released in 2014 by the artist David OReilly. The main view is of a mountain, which the player can rotate and observe as time and weather pass by. There are no goals or objectives. Like *Emissaries* mentioned earlier in the handbook, *Mountain* offers a contemplative experience for the players in the form of a virtual environment. Meaning is completely open to interpretation as subtle changes and events alter the mountain landscape over time.

This game is a challenge to traditional game immersion in removing complicated mechanics and focusing on observation instead. There isn't something to "run and gun" or a sequence of platforms to cross (these are game genres). I add it here as an example of minimalistic game design and intensifying the variable of time to challenge players perception of gameplay. Immersion can be contemplative and introspective through such ambient experiences. Finally, it challenges what play is. I question whether a player must always be looking at the screen to feel immersed, and whether they must always be looking at the screen to be considered playing. Maybe play is opening the game and setting it aside in a similar sense to playing music.

Design Conjecture

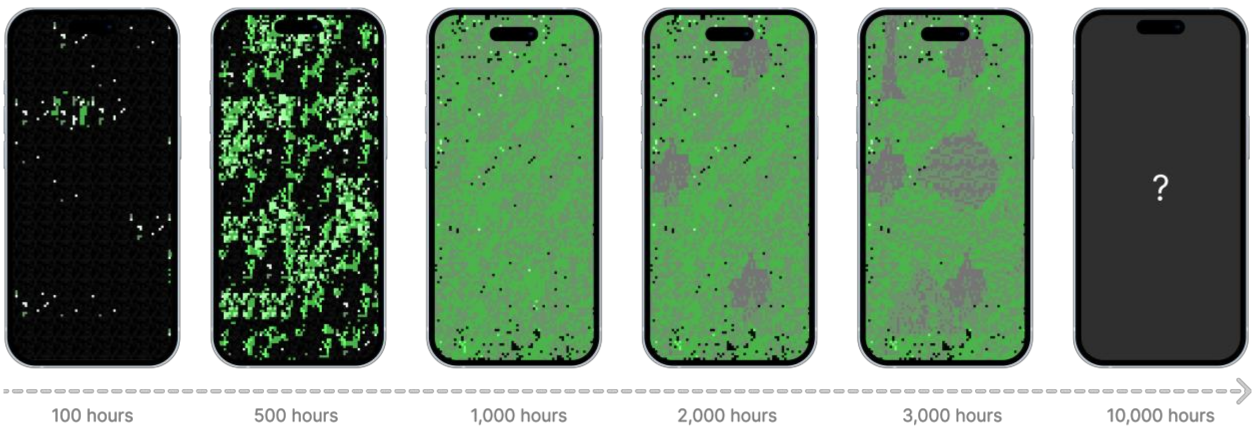

Figure 20

This is an idea from a project I created over a year ago and continue to explore. I use the notion that it takes 10,000 hours to become an expert at something and try to connect it to forest time or tree time. A player can install the game onto their phone and at first, they'll start with an asphalt parking lot, or a nearly black screen. As the game stays open, time will be accounted for, and pixels of green will begin to appear. Over time, the asphalt lot will crack, become a meadow, and eventually a forest.

My goal for this project is to break the player away from the dark patterns of endless online information feeds and encourage them to spend this time gaining a skill that they care for. It might be the case that they have a different plot of land for each skill they are learning so they can visualize their time spent learning the skill through the game itself. I believe it immerses themselves in the game of becoming an expert while having a visual component to show for it. Lastly, it challenges the idea of how long it takes for a forest to grow and might cause introspection in those who chop down trees as though they can buy another fifty-year-old tree at Walmart.

Further Readings

1. *A comparison of the restorative effect of a natural environment with that of a simulated natural environment* (Kjellgren & Buhrkall, 2010)
2. *Analysis: The Psychology of Immersion in Video Games* (*Analysis: The Psychology of Immersion in Video Games*, n.d.)
3. *Could Nintendo's Animal Crossing be a tool for conservation messaging?* (Fisher et al., 2021)
4. *Dark Patterns in the Design of Games* (Zagal et al., n.d.)
5. *Designing a Virtual Arboretum as an Immersive, Multimodal, Interactive, Data Visualization Virtual Field Trip* (Harrington et al., 2021)
6. *Diversity of Immersion Mechanics in Videoludic Novels* (Lescouet & Dumoulin, 2023)
7. *Embodying Environmental Relationship: A Comparative Ecocritical Analysis of 'Journey' and 'Unravel'* (Guanio-Uluru, 2021)
8. *Evaluation of the Effects of Music and Poetry in Oncologic Pain Relief: A Randomized Clinical Trial* (Arruda et al., 2016)
9. *Expanding the magic circle: Immersive storytelling that trains environmental perception* (Doonan et al., 2023)
10. *Experiencing Nature: Embodying Animals in Immersive Virtual Environments Increases Inclusion of Nature in Self and Involvement With Nature: EMBODYING ANIMALS IN IMMERSIVE VIRTUAL ENVIRONMENTS* (Ahn et al., 2016)
11. *Flow and Immersion in Video Games: The Aftermath of a Conceptual Challenge* (Michailidis et al., 2018)

12. *Gamification: Concepts, Methodologies, Tools, and Applications* (Management Association, 2015)
13. *How Final Fantasy VII radicalized a generation of climate warriors* (Hirst, n.d.)
14. *Immersion Through Video Games – USC Viterbi School of Engineering* (*Immersion Through Video Games – USC Viterbi School of Engineering*, n.d.)
15. *In-Game: From Immersion to Incorporation* (Calleja, 2011)
16. *MACHINES ARE OUT, GARDENS ARE IN* (Kane, 1987)
17. *More Human than Non/Human: Posthumanism, Embodied Cognition, and Video Games as Affective Experience* (Lyons & Jaloza, n.d.)
18. *Motivational game design patterns of 'ville games* (Lewis et al., 2012)
19. *Narratives of environmental crisis in Chrono Cross: settler colonialism, inter-species conflicts, and environmental injustice* (Silva & Silva, 2023)
20. *Non-Human Gaming: Video Games for the Post-Anthropocene* (Ruffino, 2018)
21. *Online Games Can Deepen Our Attention to Ecology | Sierra Club* (*Online Games Can Deepen Our Attention to Ecology | Sierra Club*, n.d.)
22. *Pixelated nature: ecocriticism, animals, moral consideration, and degrowth in videogames* (Navarro-Remesal, n.d.)
23. *Representing Amphibian Perspectives in a 3D Game Engine* (Lawal et al., 2023)
24. *Revising Immersion: A Conceptual Model for the Analysis of Digital Game Involvement* (Calleja, n.d.)
25. *Story Immersion of Videogames for Youth Health Promotion: A Review of Literature* (Lu et al., 2012)
26. *The Garden in the Machine: Video Games and Environmental Consciousness* (Brown, n.d.)
27. *The Impact of Immersive Technology on Nature Relatedness and Pro-Environmental Behavior* (Soliman et al., 2017)

28. *The interplay between immersion and appeal in video games* (Christou, 2014)
29. *The Relationship between Player Involvement and Immersion: an Experimental Investigation* (Herrewijn et al., n.d.)
30. *Time perception, immersion and music in videogames* (Sanders & Cairns, 2010)
31. *Virtual Nature: Investigating The Effect of Biomass on Immersive Virtual Reality Forest Bathing Applications For Stress Reduction* (Masters et al., 2022)
32. *What Makes a Garden a Healing Garden?* (Stigsdotter & Grahn, n.d.)
33. *What's wrong with virtual trees?* Restoring from stress in a mediated environment (De Kort et al., 2006)

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