WHITE PAPER

Games & Innovation:
The Role of Games in Societal Innovation

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Executive Summary
This white paper explores the profound impact of gaming on various sectors of society, underlining the interconnectedness between game development, technological advancements, and societal innovation.

We begin by tracing the relationship between technology and interactive entertainment experiences before the advent of video games. This section highlights the interplay between societal changes, technological innovations, and the creation of new playful experiences. We look at the Phantasmagorias of the 19th century, immersive horror theater shows that utilized mobile projectors and sensory stimulation to create terrifying experiences which in many ways are comparable to today's virtual reality horror games. We also discuss the rise of arcades enabled by advancements in lighting and steel construction, which incorporated early projection technologies and phonographs, showing that as we reinvent the shape of play to fit new environments, we rely on technological advances as well as contribute to innovation that leads to benefits outside of the field of entertainment.

The paper then describes gaming's role in the home computer revolution. It showcases how the design of the groundbreaking Apple II computer was built on insights from arcade game development, with its co-creator, Steve Wozniak, envisioning that a computer capable of playing games "could do anything." We also discuss the Commodore Amiga, the first home computer with dedicated chips for audio and graphics. The computer was made to challenge home gaming consoles, but represented a significant step forward in home computers hardware architecture, resulting in new application areas.

Next, the paper outlines how gaming technologies have influenced sectors beyond entertainment. We delve into the use of gaming engines and augmented reality in the preservation of cultural heritage, exemplified by virtual reproductions of historical sites and artifacts. We also show the impact of game engines on architecture, construction, and car design, allowing for real-time design modifications and the creation of photorealistic visualizations at impressive speeds.

We then cover the role of gaming in education, showcasing how flight simulators, initially born from arcade and home computer games, revolutionized pilot training. The paper also highlights the application of game-based technology in firefighting and medical training, enabling immersive and safe virtual learning environments for those in high-risk fields.

In the following section we examine the connection between gaming and artificial intelligence (AI), starting with Alan Turing's *Imitation Game*, which established games as testbeds for modeling non-human actors, up to recent breakthroughs in AI systems trained by playing video games.

Finally, we look at how computer games have shaped our online lives by facilitating networked social interaction and digital economies long before the emergence of modern social media. Games also serve as content creation tools for the entertainment industry, including sports and broadcasting, while streaming platforms like Twitch have influenced the rise of user-generated content and digital broadcasting.

Our paper highlights the beneficial effects the game industry has had on various domains and game developers will undoubtedly continue to play an important role in pushing the boundaries for technologies that can change all aspects of life. With this great potential for impact comes a great responsibility. In order to rise to this challenge, the game industry has to take greater ownership of the role games play as a dynamo for societal innovation and improve equitable participation.

Key Takeaways

- Games have historically both, been influenced by, and driven technological advancements beyond the gaming industry itself.
- The design and capabilities of home computers, including their ability to generate color graphics and sound, were heavily influenced by game development.
- Game technology such as virtual reality, augmented reality, and 3D modeling tools, has revolutionized sectors like archaeology, architecture, industry prototyping, and design.
- Games are instrumental in training and education, with simulations and game-based technology now used in aviation, firefighting, medical training, and disaster response.
- Games have been essential to the development of artificial intelligence from the very beginning, serving as proving grounds for training non-human actors and major advancements in machine learning.
- The game industry has a responsibility for the role games play as a dynamo for social change and innovation, and has to improve equitable participation in order to rise to this challenge.

A Trail of Hidden Connections

Games have always played an integral part in peoples' lives. We have always sought out collaborative, competitive, social spaces of playful engagement with others. Woven through this history is a story of material and technological development, one both supporting and extending the kinds of games people engage with. Yet those developments generally don't stay contained within the gaming space, but flow back out to other areas of society, often providing waypoints or inspiration for further innovations. This is a virtuous circle with gaming as a core part of the circuit.

Figure 1: An artist's rendition of a phantasmagoria.

The interplay between technological innovation and societal change has been present in the creation of interactive entertainment experiences long before video games entered the scene.

We can take Phantasmagorias (fig. 1) as an example. Popular in 19th century Europe as a form of immersive horror theater. These machines combined oral presentations with one or more magic lanterns (fig. 2) that projected frightening images, such as skeletons, demons, and ghosts onto walls, smoke, or semi-transparent screens, typically using rear projection to keep the lantern out of sight.

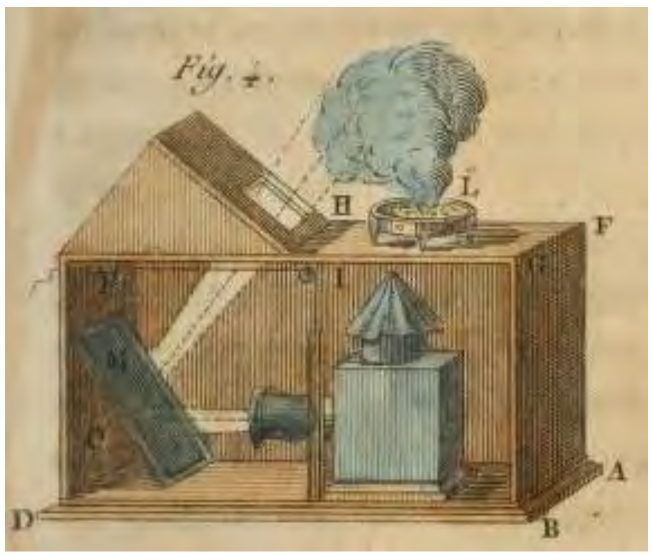

Figure 2: Hidden magic lantern.

Performers used mobile or portable projectors to make the images move and change size, while multiple projecting devices allowed for quick switching of different images. Some shows added a variety of sensory stimulation, including sound effects, smells, and even electric shocks.

Figure 3: Arcade in Adelaide, 1886.

In the later half of the 19th century, arcades—covered walkways with a diverse selection of products and experiences—became popular (fig. 3). These new urban environments came about as a result of technical breakthroughs such as gas lighting and advancements in steel construction; the same technology that lead to engineering feats like the construction of the Eiffel Tower in 1889. Arcades offered an opportunity for people to come together and enjoy strolling the urban space while also exploring novel experiences.

With these changes came a need to make the kind of experiences that the phantasmagorias had provided more compact. The answer was so-called

EXAMPLES – HOME COMPUTER REVOLUTION

Commodore Amiga. Jay Miner, the co-founder of Amiga who led the design of the original Amiga computer, claimed that his goal was to create a machine with "the graphics of a good flight simulator." He championed the idea that powerful graphics had broad value to business, educational, and entertainment applications.

Myst and the CD-ROM. The 1993 Macintosh computer game *Myst* featured pre-rendered 3D graphics designed for the CD-ROM. The game's unprecedented popularity led to a surge in the sale of CD-ROM drive.

Doom and Graphics Cards. The 3D first-person shooter game Doom (1993) was so successful that it had a direct impact on the speedy evolution of PC graphics cards. These have, in turn, found application areas as far afield as video editing, machine learning, and bitcoin farming.

"peeping boxes," which combined the latest projection technologies with new technical developments such as Edison's phonograph (1878).

The progression from phantasmagorias and peeping boxes to today's virtual reality (VR) horror games shows how changes in our everyday lives lead to the need for reinventing the format of play experiences. As games transform in step with broader cultural movements, game developers are forced to increase their technological sophistication. And as people continue to seek out playful and otherworldly experiences, artistic and technological developments are pushed even further; which in-turn benefits many other areas where these technologies can be applied.

The purpose of this white paper is to provide some modern examples of the effect that developments and innovation in the game industry has had on society. To that end, we are presenting materials that can be understood as beneficial in general terms, rather than supporting specific national or corporate interests. Examples from the military industry are outside the scope of this study. Instead, we focus on how gaming has impacted everything from the first home computers to AI, vocational training, education, cultural heritage projects, entertainment and our online lives.

How Play Drove the Home Computer Revolution

It is difficult to even imagine what the developmental arc of home computers would look like if games had not been a driving motivator. The groundbreaking Apple II (1977) computer was primarily designed by Steve Wozniak, an engineer who had just created the arcade game *Breakout* (1976) for Atari. His philosophy was that if the computer could play games, it could do anything, and this outlook influenced every aspect of the Apple II's design. This is Wozniak's description of the version of the programming language BASIC that came with the Apple II computer, a version which he originally called GAME BASIC [1]:

> *I called Steve Jobs over to my apartment, and we sat down on the floor next to the cables snaking into my TV that had the back off of it so I could get wires inside, and I showed him how I could change the colors of things, change the shape of the paddle, and change the speed of the ball with an easy BASIC command. … And [the fact] that a fifth grader could program in BASIC and make games like Breakout? This was going to be a new world; we saw it right then.*

The Apple II's hardware, including its ability to display color graphics and generate sound, was also designed around gaming needs. The computer was even originally bundled with two game paddles so that people could play *Breakout* (fig. 4). Its color graphics turned out to be what set the Apple II apart from the competition at the time, and was such an integral part of the company's brand identity that the company adopted a rainbow-colored apple logo from 1977 to 1984.

The next significant step in home computer system architecture came from one of Apple's competitors: the 1985 release of the Commodore Amiga. This

EXAMPLES – RECONSTRUCTION, CONSTRUCTION, AND SIMULATION

Their Memory. Edinburgh's Lady Haig Poppy Factory was founded in 1926 with the goal of employing veterans with disabilities. A 2018 VR project called *Their Memory* features virtual versions of veteran's workstations, and archival audio recordings recounting their experiences.

was the first home computer to feature dedicated chip sets for audio and graphics. The Amiga's design was led by Jay Miner, who had worked on the custom integrated circuits for the classic video game console Atari 2600 [2]. While hobbyists and early game developers used the home computer to create new play experiences, it also represented a pivotal development in the expansion of the computer industry. As we will discuss in more detail below, the Amiga was instrumental in innovations within the media and entertainment sector.

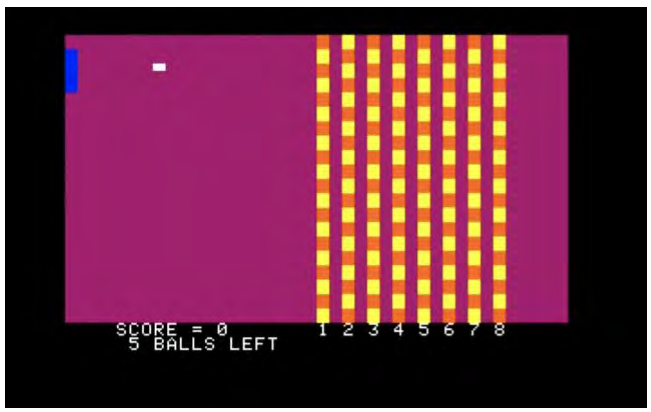

Figure 4: *Breakout* on Apple II.

While the Amiga represented a great technological leap forward, its proprietary chip set proved difficult to upgrade. Instead, IBM PC compatible computers with an open standard for dedicated graphics cards took over the market, and have dominated high-end gaming ever since. Today, graphics processing units are essential hardware for driving breakthroughs in artificial intelligence. In the quest to design AI that can solve complex, real-world problems in record time, OpenAI's team of five bots trained by playing video games at an unprecedented scale, a feat that required 256 GPUs and 128,000 CPU cores [3].

Reconstruction, Construction, and Simulation

Archaeology has become a convergence point for a number of different technologies and approaches stemming from games. The use of game engines, forms of visualization, and experiential approaches have been powerful tools in recreating spaces and artifacts from the past. The publisher Ubisoft, known for the *Assassin's Creed* game franchise which takes place in historical settings, collaborated with the Smithsonian Museum of Asian Art to create the *Age-Old Cities* VR experience (fig. 5) [4]. In it, the participant moves through a number of settings in Syria and Iraq, ranging from 2000 BCE to the 19th century, exploring sites that have long since been destroyed. Rather than just model the environments, Ubisoft brought them to life by adding people and soundscapes.

The Chinese technology company Tencent and Dunhuang Research Academy have also reconstructed historical environments in the Digital Grotto Project. The online museum uses game technologies such as global dynamic lighting to virtually reproduce scenes the Library Caves of Dunhuang. Visitors can actually "walk into" the Library Cave in high-definition 3D for an immersive experience and interact with historical figures. They can also examine 21 pieces of manuscripts, documents, and silk paintings dating from the 4th to 11th century CE [5].

Game inspired technology is also being used to augment historical sites and collections. Instead of relying on total recreations in VR, augmented reality (AR) allows for a blending of actual and recreated material. By combining AR technology with location tracking, game-like experiences similar to Niantic's super hit *Pokémon Go* are becoming commonplace in museums and cultural heritage sites. AR has also become a means for the public to explore heritage sites that are otherwise off-limits [6].

Figure 5: *Age-Old Cities VR* experience.

These kinds of developments are also powerful for the way they leverage the public's familiarity (especially young people) with a play modality for other purposes. Rather than seeing Pikachu through their phones, players are confronting rare or ancient artifacts that might otherwise be lost to time. For example, a team of researchers recently combined 360-degree panoramic images of Antalya, Turkey, with 3D modeling software to create a low-cost, accessible VR game that allows players to virtually travel the Silk Roads [7].

Game technology is also leading to new and improved architecture and construction practices outside the realm of preservation. The power and speed of computer graphics game engines allow architects and designers to create highly detailed 3D buildings and interiors without the prohibitively long rendering time necessitated by older 3D modelling tools. The result is a more agile, flexible design process, in which an architect can make changes to a photorealistic building in real time. Companies that specialize in creating "digital twins," or virtual representations of physical objects, have even used Unreal Engine to turn satellite and drone data into 3D replicas of whole cities like Shanghai, Singapore, and Helsinki (fig. 6) [8].

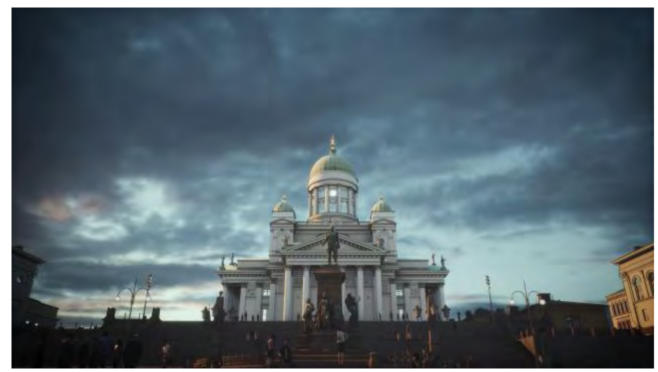

Figure 6: Virtual twin of Helsinki.

The unique ability of game engines to generate extremely realistic 3D objects have made them attractive tools for a number of industries, particularly those looking to reduce the time and expense that goes into creating large or impractical physical models [9]. Much as in the world of architectural visualization, car companies like the

EXAMPLES – TRAINING AND EDUCATION

Gather.town. This software uses RPG-inspired maps and avatars to create "virtual headquarters" for remote teams. A 2022 study found that nursing students who received training via a Gather.town RPG had better learning outcomes than those who used video-based lessons

MR.Brick. Researchers found that incorporating mixed reality (MR) into young students' educational games led to better collaboration.

Sea Hero Quest. This mobile game and its VR sequel collect players' spatial navigation data via head and eye tracking, which scientists can use to study early signs of dementia. It was reported that two minutes of *Sea Hero Quest* playtime contributes the same amount of data as 5 hours of lab-based research.

BMW Group, Volkswagen, Subaru, and Rivian use Unreal Engine throughout multiple stages of the vehicle design process (fig. 7) [10], rapidly prototyping detailed models for design review, user research, and even testing AI for self-driving cars [11].

Figure 7: A Volvo rendered in Unreal Engine.

Autonomous driving aside, cars are rapidly becoming more intelligent, utilizing multiple sensors, cameras, and algorithms in an attempt to make the driving experience as safe and efficient as possible. With an increasing amount of data to collect, calculate, and translate for the driver, car manufacturers must ensure that their vehicles' computers are powerful enough to make these calculations quickly and reliably. What's more, their user interfaces must represent this data to drivers in a way that is not only visually appealing, but easy to parse and act upon. To this end, Volvo recently announced that they are using Unreal Engine to generate photorealistic visualizations of the car's surroundings, including any obstacles or hazards, and display them to the driver without becoming distracting or "overwhelming" [12].

Training and education

It is no surprise that video games have had a far-reaching impact on many areas of education and training. Learning is a significant part of so many gameplay experiences. Players build an understanding of the game system through repeated encounters, gradually perfecting their skills and knowledge. Learning is also connected to why we *stop* playing games. Players often report that the better they understand a game system, the less reason they have to keep playing it, instead preferring to move on to new learning challenges. This cycle of challenge, learning, and plateau has been a powerful modality in the gaming space that transfers well to a variety of training and educational environments.

While there is a long history of PC gaming in schools, there is a broad set of examples worth highlighting. For example, virtual training environments are particularly useful when the skill acquisition imposes physical danger on the participants. Flight simulators have, for instance, completely altered the way pilots learn how to fly, and are especially useful for practicing challenging maneuvers like flying during extreme weather conditions.

The first commercially available flight simulators were actually games made for arcade cabinets and home computers. Microsoft's *Flight Simulator* (1982) was born out of a series of articles written by software engineer Bruce Artwick about home computers' implementation of 3D graphics. Indeed, new versions of *Flight Simulator* are still being developed, and continue to play an important role in pilots' training. In 2007, Microsoft announced their Enterprise Simulation Platform which would allow companies to integrate the same simulation technology found in *Flight Simulator* in their own products. Lockheed Martin purchased the platform in 2009, which is no surprise given that flight simulators are integral to the process of designing and developing new aircraft. [13]

Figure 8: *Flaim Trainer*'s VR program.

Several other high-risk domains have benefited from simulated training via game-based technology. *Flaim Trainer* (fig. 8) is a firefighting simulation that uses VR technology to create an immersive firefighting experience without the risks, costs, or environmental impact found in traditional solutions [14].

Simulations are also used to enhance medical training. In a randomized study of over 300 physicians, researchers found that those who were given *Night Shift* (fig. 9), a trauma center simulation game, showed improved triage decision-making compared to those who'd received the same training via a traditional educational app [15].

Figure 9: *Night Shift* gameplay.

The academic paper *Practical Insights into the Design of Future Disaster Response Training Simulations* (2018) points to a future where virtual environments will play an even greater role in training for disaster scenarios [16]. Innovations in data collection will lead to more robust and accurate skill assessment, and improvements to procedural generation will mean simulations can be played again and again without becoming repetitive.

Digital Mind Games

At this moment when so many of us are playing with ChatGPT and entire sectors are reorienting how they operate, perhaps the current boom of AI provides one of the most evocative domains to explore the links between gaming and technological

EXAMPLES – DIGITAL MIND GAMES

Emergent Skill Progression in Tool Use. Researchers at OpenAI and Google have used "virtual playgrounds" where artificial agents play team-based games like hide-and-seek to develop tool use skills. They observed highly emergent behaviors like fort building and ramp exploits.

Machine Learning for Character Animation. Nvidia, Toronto University, and University of California, Berkely have collaborated on creating smooth and natural character movement in virtual environments. This is a difficult and resource intensive task where machine learning can be applied to create life-like behavior in virtual agents.

development. The study of artificial intelligence has always been directly connected to games. In Alan Turing's classic 1950 paper, *Computing Machinery and Intelligence*, he describes what he calls the *Imitation Game,* a concept which was iterated upon until it eventually became known as the Turing test. In the *Imitation Game,* one player assumes the role of an interrogator who must determine which of the other two players is a man and which is a woman. They do so by sending written questions to the players in the other room, at which point the players' send back their written answers. The object of the game is for the two players (one man and one woman) to try to make the interrogator guess wrong. After he describes the rules, Turing asks: "What will happen when a machine takes the part of the man in this game? Will the interrogator decide wrongly as often when the game is played like this as he does when the game is played between a man and a woman? These questions can replace the question: Can machines think?" [17].

Turing estimated that computers would be able to pass the Turing test within fifty years, but he also predicted that the question would have become irrelevant by then. History has essentially proven him correct, as the Loebner Prize competition for most human-like chatbot was discontinued in 2020. But Turing's thought experiment established games as proving grounds for modeling non-human actors in ways that go far beyond mimicking small talk.

In 1996, British computer scientist Steve Grand and the CyberLife development studio created a series of video games known as *Creatures* (fig. 10). These games, in which players raised and protected members of a species called Norns, were an early example of an artificial life simulator. Instead of constructing complex logic systems in the pursuit of intelligent behavior, Grand provided the basic mechanisms of life such as digital DNA, neural network brains, reproductive capabilities, and a suitable habitat to adapt to, and then let the system evolve over the course of gameplay, hoping for some sort of intelligence to emerge as a result. This approach made *Creatures* an early example of machine learning.

Figure 10: *Creatures* gameplay.

While this early exploration of machine learning is an important but lesser-known example in the history of games as a testbed for computational development, the game that most people connect with advancements in AI is probably chess. In the paper *Programming a Computer for Playing Chess* from 1950 (notably the same year as Turing's paper), mathematician Claude Shannon conservatively estimated the number of possible chess games to be at least 10 to the 120th power, which is about twice as many as there are atoms in the Milky Way galaxy [18]. A game with a small number of rules that combine and yield large numbers of game variations is known as a game of emergence, and indeed, these games have turned out to be excellent proving grounds for AI models in general and machine learning models in particular.

Figure 11: Garry Kasparov playing chess against Deep Blue.

The previously mentioned Shannon paper is generally considered to be the beginning of chess AI, but the discipline's first fifty years mainly just focused on what's known as the brute force method. In this method, human chess strategies are encoded and combined with the computer's superior ability to evaluate large amounts of potential future positions before making each move. This approach culminated in a two-part spectacle where the world chess champion, Garry Kasparov, played the IBM Deep Blue chess computer in a series of tournament regulations matches (fig. 11). In the second match, Deep Blue defeated the world champion.

At the time, Kasparov had an Elo rating (a system to measure the relative strength of chess players) of 2785, and Deep Blue's rating was estimated to be about the same. But the rapid improvement of computer hardware meant that human players could no longer keep up with the chess engines. Although no human player has been able to reach a rating of 2900, by 2008 there were at least five chess engines with an Elo rating over 3000. In Kasparov's words: "Today you can buy a chess engine for your laptop that will beat Deep Blue quite easily" [19].

As a result, AI research had to find a new challenge. They found Go. This game is even more complex than chess, stemming from the fact that the board is bigger (usually 19x19 squares with stones placed on the corners of the squares) and players have more choices on their turn. Despite the power of today's computers, the brute force approach of Deep Blue isn't enough to beat the best Go players in the world, so the AI researchers turned to machine learning to get an edge. AlphaGo is a program that uses several layers of neural networks. The system was initially trained on human games and then started playing against instances of itself [20]. In 2016, AlphaGo defeated the world champion Lee Sedol 4-1. In 2017, AlphaGo Zero, a model completely trained by playing itself, surpassed AlphaGo. Later that same year, AlphaZero, a general-purpose model that trained itself beat the

EXAMPLES – ONLINE LIVES

Active Worlds. ActiveWorlds is an online virtual world released in 1995. It allows participants to navigate a 3D environment with animated avatars. Participants can also make their own contributions to the environment, like building their own home, in real-time.

EVE Online. The Icelandic massively multiplayer online game EVE Online has an in-game economy that is so expansive and advanced that economists have used it to study real economic theories and "shine new light on modern econometrics."

human world champions in chess, go, and shoji (Japanese chess).

As AI advanced by training on increasingly complex games, it became more suitable for broader applications. AlphaStar, the first AI to defeat a professional StarCraft II player in 2019, boasted a neural network that could predict a long string of actions over an extended period of time, making it ideal for "weather prediction, climate modeling, and language understanding" (fig. 12) [21]. In 2022, the AI known as AlphaTensor discovered a more efficient method for multiplying 4 x 4 matrices, improving upon the algorithm used for over 50 years, and it did so by treating matrix multiplication as a game [22]. As explained by machine learning engineer José Villagrán, this discovery has direct applicability to the problem of self-driving cars, whose processing system utilizes matrix multiplication in order to analyze an environment and avoid collisions [23].

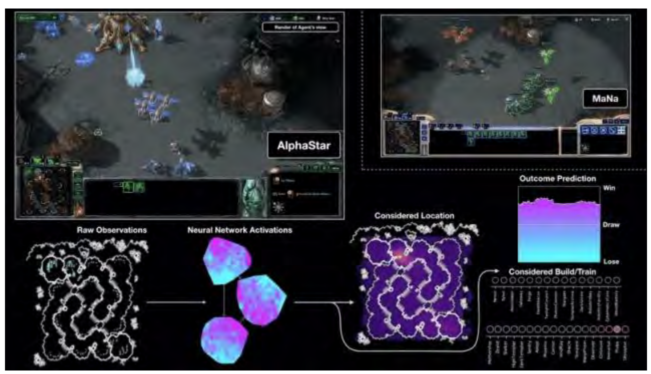

Figure 12: DeepMind's visualization of AlphaStar's match against a human player.

The use of gaming to explore, challenge, train, and push systems goes back to the earliest days of computation. The deep relationship between games and AI is a powerful representation of the cycle of play, research, and technological development. It highlights not only how gaming plays a practical role in innovation but how it acts as a powerful imaginative lever, helping researchers envision new challenges and horizons to strive toward.

Online Lives

In the paper *Games Matter* from 2022, sociologist and media studies scholar T.L. Taylor writes, "Before Instagram, Facebook, Twitter, and all the other platforms that we now umbrella under the term 'social media' sites for real-time social interaction via the internet already existed—computer games" [24]. Whether it was connecting university mainframes through Arpanet, the predecessor to the internet, or by connecting home computers to networks of local hubs known as Bulletin Board Systems (BBS), as soon as people were first able to connect their computers to each other, they used the technology to play games.

In the earliest days of bulletin board systems, players found ways to push networking to play together, either in turn-taking systems or in real-time across geographical distances. Once early internet infrastructure fell into the hands of university students, they found ways to create synchronous virtual environments in which to game together. First developed in 1978, MUD (multi-user dungeon) created by Richard Bartle and Roy Trubshaw as students in the UK, was a text-based multiplayer world, extending single-player games

Colossal Cave Adventure (1976) (fig. 13) and *Zork* (1977) into networked experiences. After its release, the game quickly spread to colleges around the world, where students created their own versions. As game hobbyists began to push the limits of networking, graphics, and computation, shared, massively populated virtual game worlds sprung up, from *EverQuest* (1999) to *World of Warcraft* (2004) (fig. 14).

Figure 13: Colossal Cave Adventure.

As people played these games, they explored, and repurposed, third-party websites and applications to help facilitate their play. Early virtual spaces like *Second Life* (2003) paved the way for both social and corporate uses of sandbox environments that allow users to create entire worlds for both play and work. In all of these we find early examples of online real-time interaction, user-generated content, and dynamic online economies.

Well-predating Facebook and Twitter, or the rise of cryptocurrency and digital goods, these gaming spaces reshaped our culture to accommodate connection, community, and economy at a distance and digitized. Online gaming also completely reframed how software production and release is done, moving an industry toward a model of software as a "service," and structuring around ongoing iteration and releases in concert with the growing and changing needs of its users. What we now take for granted in our online lives—connecting with family, friends, and even strangers, co-creating content and culture on virtual platforms, and transacting in digital currencies—was first undertaken in gaming long before the rise of social media.

Figure 14: People playing *World of Warcraft* together at Blizzcon in 2011.

Media and Entertainment

As noted previously, the Amiga, one of the earliest home computers, proved a powerful device not only

EXAMPLES – MEDIA AND ENTERTAINMENT

Unreal Engine in Film and television. Studios use Unreal Engine to create everything from virtual sets, to in-camera visual effects, to new production pipelines. Their tools have been utilized on TV shows like The Mandalorian, Westworld, and Star Trek: Discovery, as well as films like The Matrix Resurrections.

BBC Together. The BBC conducted an experiment which found that Doctor Who fans found a greater sense of community while remotely watching episodes of the TV show together on Twitch. In response, they developed their BBC Together program, which hosted simultaneous synchronized viewing of BBC shows.

O2 Arena in Fortnite. In 2021, the O2 Arena collaborated with Epic Games to create a replica of the London-based venue in Fortnite, and used it to host a virtual concert for the pop band easy life.

for gaming, but as a content creation tool that was taken up by the broader media sector. While the computer was designed with a focus on games, its audio and video capabilities were so advanced that it became a popular choice for the entertainment industry. It was, for instance, used to create and render the special effects in TV shows like *Max Headroom* (1987) and *Babylon 5* (1993). And artists like Andy Warhol, Jean "Moebius" Giraud, "Weird Al" Yankovic, Todd Rundgren, and the band Devo all used the Amiga to make music videos and other digital media creations (fig. 15).

Figure 15: Still from music video created with the Commodore Amiga.

Games also have a long relationship with sports, going back to the earliest days of technology. For example, in 1958 the physisist William Higginbotham used an oscilloscope to create one of the first electronic games to use a graphical display: *Tennis for Two*. But games quickly moved from simply being an outlet for sports to a generative part of an entire athletic ecology. Most sports scholars now speak of "media/sport," and gaming has proven to be a central part of the contemporary experience of sporting life. The games themselves have been taken up by professional sports organizations where they serve not only as a form of fan service, but as training devices and, more importantly, systems to augment broadcasts. As simulations, titles like *Madden* or *FIFA* are used to recreate and experiment with different scenarios, while their digital playing fields are also used for visualizations in official broadcasts. Indeed, there is a powerful aesthetic circuit between sports games and broadcast sports, where computation and visualization flow easily between the two domains, influencing each other in turn.

Games have also acted as powerful convergence devices, branching out and building audiences across multiple media sectors. Whether it is extending a film franchise or creating new ways for fans to engage with popular stories, games have simply become another part of the media landscape, and the worlds they envision are regularly extended into film and TV productions.

We have also seen streaming platforms like Twitch (launched in 2011 as Justin.tv) act as early experiments in forms of user-generated content and distributed digital broadcasting. Watching other people play has long been a central part of gaming culture. For several decades now, enthusiasts have cobbled together all kinds of technologies (from off-the-shelf mixing boards to advanced networking architecture) to try and broadcast their play to other fans. The work of these early companies and gamers served as a powerful (but unacknowledged) proof of concept to platforms like Netflix, Hulu, and HBO. It is worth noting that, during the pandemic, many non-gamers found themselves turning to sites like Twitch for entertainment out of necessity. Musicians, artists of all stripes, even politicians, leveraged streaming capabilities (fig. 16) that had up until that point been the purview of gamers.

Figure 16: Congresswoman Alexandria Ocasio-Cortez playing *Among Us* on Twitch.

Conclusions

In the 1938 book *Homo Ludens*, Dutch cultural theorist and historian Johan Huizinga says that play communities derive their power from "the feeling of being 'apart together' in an exceptional situation, of sharing something important, of mutually withdrawing from the rest of the world and rejecting the usual norms." [25] For those of us who have studied games and play for decades, the overlap with beneficial conditions for creativity and innovation are evident.

If we probe a bit more deeply into the nature of play. If we look at what makes a game appealing, it tends to come from reaching unexplored areas of a possibility space. It comes from exploring new challenges and limits, which means taking risks. It means saying, "Let's try it, and see what happens" without knowing what the answer will be. We have described games and the game industry as a proving ground for ideas in a number of different areas, but the environmental conditions for the generation of ideas and technology that can drive societal change may be even better described as a playground.

But the sense of being apart together outside of the confides of regular society may also have led to some of the issues the game industry is struggling with. The tech industry in general, and the game industry in particular, has not just been a playground but a boys' club that too often shirks the responsibilities that come with the powerful position it has. There is important work still ahead, to fully embrace diversity, equity, and inclusion.

The video game industry will no doubt continue to play an important role in serving society with an array of technological advancements and in doing so, it has to make sure all voices are heard.

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