VIRTUAL REALITY
FOR GLOBAL CLIMATE LEADERSHIP

Atlantic Council

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FOUNDATION RESILIENCE CENTER
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STRATEGY AND SECURITY

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Adrienne Arsht-Rockefeller Foundation Resilience Center

Driven by the critical need to find immediate, scalable solutions to address the widespread and intensifying consequences of climate change—threatening our families and communities, natural ecosystems, economic development, and political stability—**the Adrienne Arsht-Rockefeller Foundation Resilience Center (Arsht-Rock) set out to reach one billion people with resilience solutions by 2030**.

With the convening power of the Atlantic Council and the vision and support from our founders Adrienne Arsht and The Rockefeller Foundation, **Arsht-Rock builds individual and community resilience in the face of climate impacts**.

In the years since we launched the center in 2019, **we have been committed to enabling individuals, communities, and institutions to prepare for, navigate, and recover from natural and human-caused shocks and stressors, both expected and those not yet imagined**. Leveraging the expertise of our cross-disciplinary team, our global network of partners, and collaboration with policymakers at all levels, we take bold action to improve lives, reduce inequity, and increase human security.

We believe a better future is possible. While climate change is a challenge, it is also an opportunity to invest in our communities and drive change at scale. By collectively creating integrated, inclusive, and multi-benefit solutions, we can make an impact on people's lives, health, and livelihoods for generations to come.

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This report has been authored by Peter Engelke, *Deputy Director and Senior Fellow for Foresight, Scowcroft Strategy Initiative, Scowcroft Center for Strategy and Security* and Rosemary Mann, *Director, Strategic Initiatives and Partnerships, Adrienne Arsht-Rockefeller Foundation Resilience Center*.

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Atlantic Council
1030 15th Street NW, 12th Floor
Washington, DC 20005

September 2022

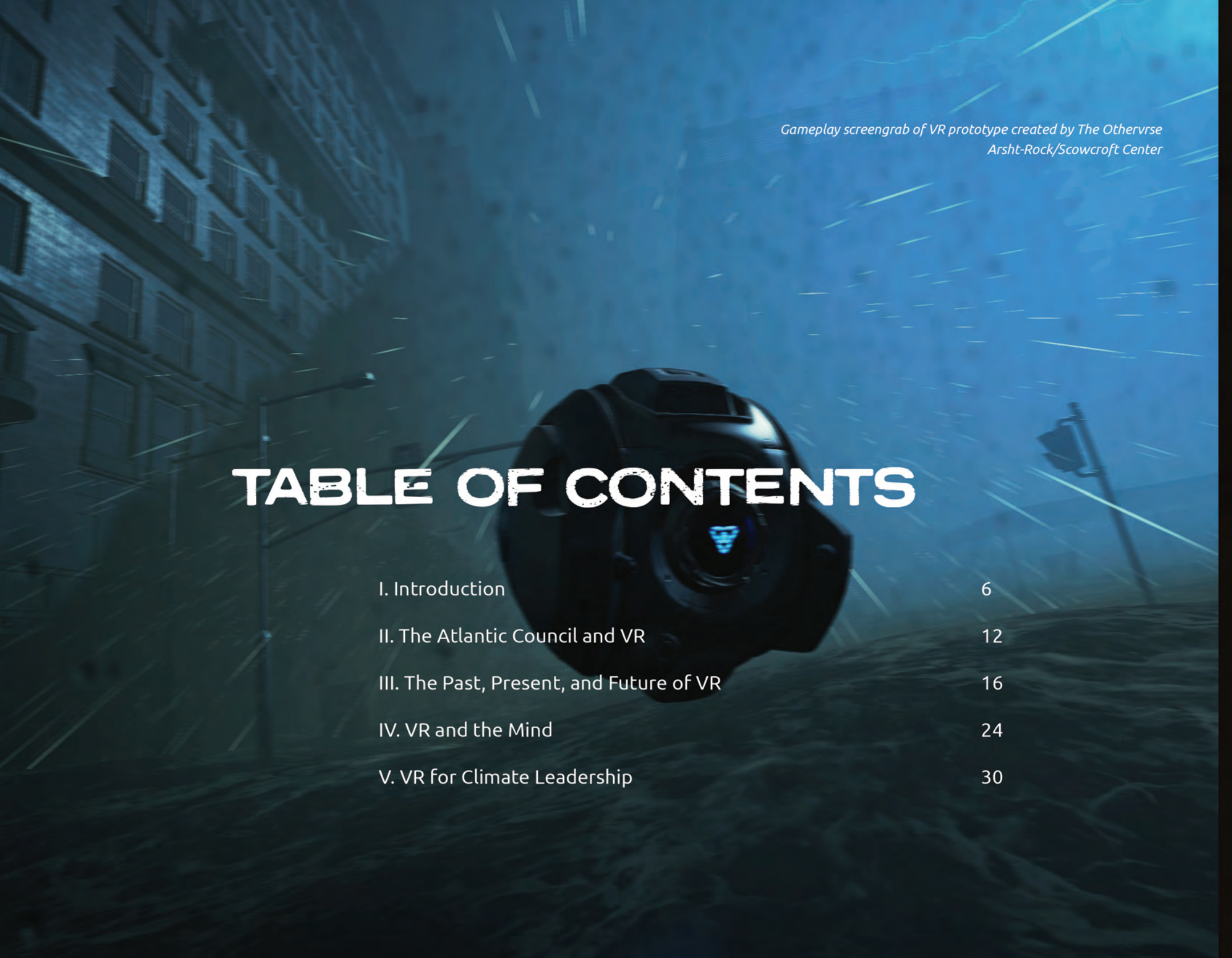
ACKNOWLEDGEMENTS

The authors wish to thank the following for their cooperation and valued contributions, including: Caspar M Ammann, *Chief Scientist and Co-Founder, Climate Strategies*; Carissa Caban-Aleman, M.D., *Associate Professor; Director of Behavioral Health Services at Student Health Center, Psychiatry and Behavioral Health, Florida International University*; Robert Catto, P*rogram Director, Full Sail University*; Paula Angela Escuadra, *Co-Founder and Co-Chair, International Game Developers Association Climate Special Interest Group*; *Chance Glasco, Nonresident Senior Fellow, Adrienne Arsht-Rockefeller Foundation Resilience Center*; Robert Goodspeed, *Associate Professor of Urban and Regional Planning, Taubman College of Architecture and Urban Planning, University of Michigan*; Andrew P. Jones, *Executive Director, Climate Interactive*; Peter Mitchell, *Chief Creative Officer, Marketing for Change Co.*; Marina Psaros, *Head of Sustainability, Unity Technologies*; Mitchell Sanchez, *Founder, The Othervrse*; Grant Shonkwiler, *Nonresident Senior Fellow, Adrienne Arsht-Rockefeller Foundation Resilience Center*; Pablo Suarez, *Innovation Lead, Red Cross Red Crescent Climate Centre*; Carlos Zegarra, *Executive Director, Sachamama.*

The authors of this report would like to acknowledge the following colleagues at the Atlantic Council for the complete implementation of this study, including: Kathy Baughman McLeod, *Director and SVP, Adrienne Arsht-Rockefeller Foundation Resilience Center*; Barry Pavel, *former Senior Vice president and Director, Scowcroft Center for Strategy and Security*; Nidhi Upadhyaya, *Deputy Director, Strategic Initiatives and Partnerships, Adrienne Arsht-Rockefeller Foundation Resilience Center*; Imran Bayoumi, *Project Assistant, Scowcroft Center for Strategy and Security*; Felix Knight; *former Project Assistant, Adrienne Arsht-Rockefeller Foundation Resilience Center*. A special thank you to our partners at Full Sail University for their continued support of our video gaming initiative.

Thanks also to Alison Bradley, *Founder, Wacky Puppy Design*, for her work on the design, layout, and graphics of the report.

Gameplay screengrab of VR prototype created by The Othervrse Arsht-Rock/Scowcroft Center



Gameplay screengrab of VR prototype created by The Othervrse Arsht-Rock/Scowcroft Center

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I. INTRODUCTION

Photo by Hans Eiskonen on Unsplash.

In *Tree*, an award-winning virtual reality (VR) experience first released at the 2017 Sundance Film Festival, a person can come about as close as was then humanly possible to feel what it is like to be another species. In *Tree*, the player embodies a kapok tree, a giant of the Central and South American rainforests. In this VR experience, the player experiences life as a kapok tree, with the player's eyes viewing the world as if from the tree's trunk and the player's own arms appearing as extensions of the tree's branches. The player moves through the tree's life stages as it grows from a seed to its mature adult stage. Players are immersed in a vivid natural forest setting, full of color, sound, light, and shadow, and populated by other plants and animals. The experience is stimulating, intense, and extraordinarily beautiful. Toward the end, however, this peaceful setting is disrupted by chainsaws, fires, smoke, yelling, and animals crying out. At this moment, the player realizes that the forest has been set ablaze by humans and that the player, embodying the kapok tree, can neither run nor defend itself. The player is reduced to watching as the tree that they have embodied burns along with the surrounding forest.[1]

[1] Tree's website is https://www.treeofficial.com. For a video showing a player using Tree, see https://youtu.be/QLpDeZhObAs. For a review of how the experience was developed, see Cliff Saran, "How the immersive VR film Tree was created," Computer Weekly, February 20, 2019, https://www.computerweekly.com/news/252457943/How-the-immersive-file-Tree-was-created.

Photo by jude chua on Unsplash.

Photo by Joanne Francis on Unsplash.

Tree has resonated with millions of people because of its storytelling, natural splendor, sensory immersion, environmental message, and first-person experience. This award-winning VR experience has been played by individuals at home and at film festivals such as Sundance, at technology conferences, and in other settings.

What separates a VR experience like *Tree* from a two-dimensional video game, a television show, or a conventional movie? Although all have value in conveying information to consumers, VR's immersive quality is what sets it apart. VR enables players to experience an alternative world differently compared with other experiences. In a well-designed VR experience, the player is taken through an alternative world that is intense, immediate, and visceral. VR therefore offers a qualitative difference between itself and everything else. Its intensely realistic depiction of alternative worlds gives VR an advantage over other forms of media, including film, video games, television, and augmented reality (AR).

For this reason, VR is often seen as a kind of empathy machine in that, as the *Tree* case shows, the player can develop a deeply powerful, even intimate, perspective on the subjects portrayed in the experience. Advocates for effective and scaled action on climate change therefore see in VR a tool for reshaping how people understand climate change. Organizations that want to leverage VR for this purpose have immense opportunity to do so. The technology continues to advance, driven by a global VR market measured in the hundreds of millions of consumers and tens of billions of dollars in revenue (see Box 1).

The purpose of this report is to examine VR in one such capacity: as a tool for shifting how a very influential group of people—current and future world leaders—perceives climate change. Although there are many VR experiences

"...VR is often seen as a kind of empathy machine...

Photo by Chris Abney on Unsplash.

Photo by Benjamin Lizardo on Unsplash.

that attempt to educate, raise awareness, and inspire people to act on climate change and other environmental problems (see Appendix 1), these experiences are often not accessed, surfaced, or made actionable within the highest levels of global leadership—whether by heads of state, government ministers, legislators, or C-suite executives. This group needs inspiration, inducements, and a healthy dose of reality-based fear to act quickly to reverse climate change. We know these leaders hold many of the most important levers of power at all levels in all sectors - and therefore have the greatest influence over whether our species will overstep the 1.5 degrees Celsius warming that scientists have found to be the tipping point for the planet.[2]

VR can be a powerful tool for use in this fight. If this technology is to be leveraged for maximum impact, then it is important to understand how its strengths can best be honed for this specific application. Leaders need tools to not just rethink their climate positions but, perhaps just as critically, to reimagine their assumptions and expectations about climate-altered futures and the policies and investments that will shape those futures. VR can be such a tool and should be deployed to its maximum value.

[2] For a review of the Glasgow conference, see Helen Mountford et al., "COP26: Key outcomes from the UN climate talks in Glasgow," World Resources Institute, November 17, 2021, https://www.wri.org/insights/cop26-key-outcomes-un-climate-talks-glasgow; Umair Irfan, "What the world did and didn't accomplish at COP26," Vox, November 13, 2021, https://www.vox.com/22777957/cop26-un-climate-change-conference-glasgow-goals-paris.

This report is informed by a multidisciplinary panel of experts and is organized as follows: Section II spells out the Atlantic Council's approach to VR as a tool for helping drive change in the world. Section III provides an overview of VR as a form of technology. Section IV discusses the relationship between the human mind and VR, emphasizing that the most effective VR experiences should be built around a few insights drawn from psychology. Section V explores VR as a tool for climate action, for reshaping how world leaders, current and future, think about climate change. Section VI offers recommendations for organizations that are interested in building VR experiences around actionable climate messaging. A short conclusion offers a vision for the way ahead, focusing on how to use VR as a powerful tool for global climate leadership.

> ***When you are in VR experiences, you'll remember them as if you were actually there. You'll have more empathy for somebody that you've met than somebody that you've just heard of, and the feeling that you're sharing the same space and maybe making eye contact with that person—it's really powerful.***
>
> ***— Vicki Ferguson, lead programmer, and Oliver Palmieri, game director, Ubisoft***

CO_2 emissions in gigatons per year 1850-2017 - The Economist.

Photo by Patrick Hendry on Unsplash.

HOW BIG IS THE VR MARKET?

BOX 1

The global VR market is large and expanding. One estimate by the consumer data company Statista estimated that the combined VR, AR, and mixed reality (MR) global markets were worth $31 billion in 2021, with a forecasted global market value reaching nearly $300 billion by 2028.[a] A study by the consultancy Grand Review Research estimated that the VR market alone is growing at 30.3% per year in value. It estimated a 2020 value of $14.6 billion, which was nearly a tenfold increase from $1.6 billion in 2016, and just a fraction of the predicted 2027 global VR market value of $92.3 billion.[b]

Market research data also suggests that East Asia is the region with the largest consumer base. Statista estimated that in 2020, Chinese consumers spent an estimated $5.8 billion on VR and AR technologies, followed by Japan at $1.8 billion. The United States was not far behind China, at $5.1 billion, while western Europe came in at $3.3 billion.[c]

[a] "Augmented reality (AR), virtual reality (VR), and mixed reality (MR) market size worldwide in 2021 and 2028," Statista, 2022, https://www.statista.com/statistics/591181/global-augmented-virtual-reality-market-size/. See also Ying Lin, "10 virtual reality statistics every marketer should know in 2022 [infographic]," Oberlo, February 12, 2022, https://www.oberlo.com/blog/virtual-reality-statistics.

[b] "Virtual Reality In Gaming Market Size, Share & Trends Analysis Report By Component, By Device, By User (Commercial Space, Individual), By Region, And Segment Forecasts, 2020 – 2027," Grand View Research, https://www.grandviewresearch.com/industry-analysis/virtual-reality-in-gaming-market.

[c] "Augmented and virtual reality (AR/VR) forecast spending worldwide in 2020, by country," Statista, 2022, https://www.statista.com/statistics/1076686/ar-vr-spending-worldwide-by-region/.

[d] "Meta's Dominance in the VR Market will be Challenged in the Coming Years, According to IDC," International Data Corporation, June 30, 2022, https://www.idc.com/getdoc.jsp?containerId=prUS49422922.

Sales of VR hardware reinforce this overall market growth. In June 2022, the market research firm International Data Corporation (IDC) reported robust (242%) year-on-year growth in VR headset shipments, driven by Meta's market share for its Oculus 2 headset. IDC asserted a likelihood of continued strong growth. Next generation headsets from Meta, Apple, Pico, and Sony are due for release starting in 2023.[d]

As with data regarding market size defined in dollars, there is tantalizing but incomplete data regarding the number of consumers who use VR. All indicators, however, show that the number of people consuming VR around the world is large and expanding. One review of the evidence placed a best-estimate global figure of active VR users in 2018 at 171 million people.[e] Another study of the U.S. market estimated that 22.5 million people used VR at least once a month in 2017 (6.9% of the total American population) and forecasted the figure to rise to 57.1 million (17.0%) by 2021 (the study was conducted in 2019).[f]

Data regarding the age and gender distribution of VR users fits some preconceived notions, with males and younger people using VR more frequently than women and older people, but here too the evidence is mixed. An examination of VR users in the United States and United Kingdom by age and gender found that males and people in the youngest age cohorts did use VR. The difference between men and women was stark: 30% of males versus 16% of women had used VR in the month before being surveyed. The data was less pronounced by age group, at least until middle age: 34%-35% of respondents 16-34 years old were more likely to have used VR in the previous month, compared with 26% of people in the 35-44 age group. Older age cohorts (45 and above) used VR far less often.[g] Other studies, it should be noted, have resulted in a less pronounced gap between male and female VR use.[h]

[e] "Forecast for the number of active virtual reality users worldwide from 2014 to 2018," Statista, February 8, 2022, https://www.statista.com/statistics/426469/active-virtual-reality-users-worldwide/.

[f] Victoria Petrock, "Virtual and Augmented Reality Users," eMarketer, March 2019, https://artillry.co/wp-content/uploads/2019/04/eMarketer-VR-and-AR-in-2019.pdf.

[g] Chase Buckle, "AR vs VR: The challenges and opportunities in 2019," GWI, November 19, 2018, https://blog.gwi.com/chart-of-the-week/augmented-virtual-reality/.

[h] Catherine Allen, "Understanding the VR market in 2021: Oculus Quest and Oculus Quest 2," Immersive Promotion Design, 2021, https://www.immersivepromotion.com/understanding-the-vr-market-in-2021.

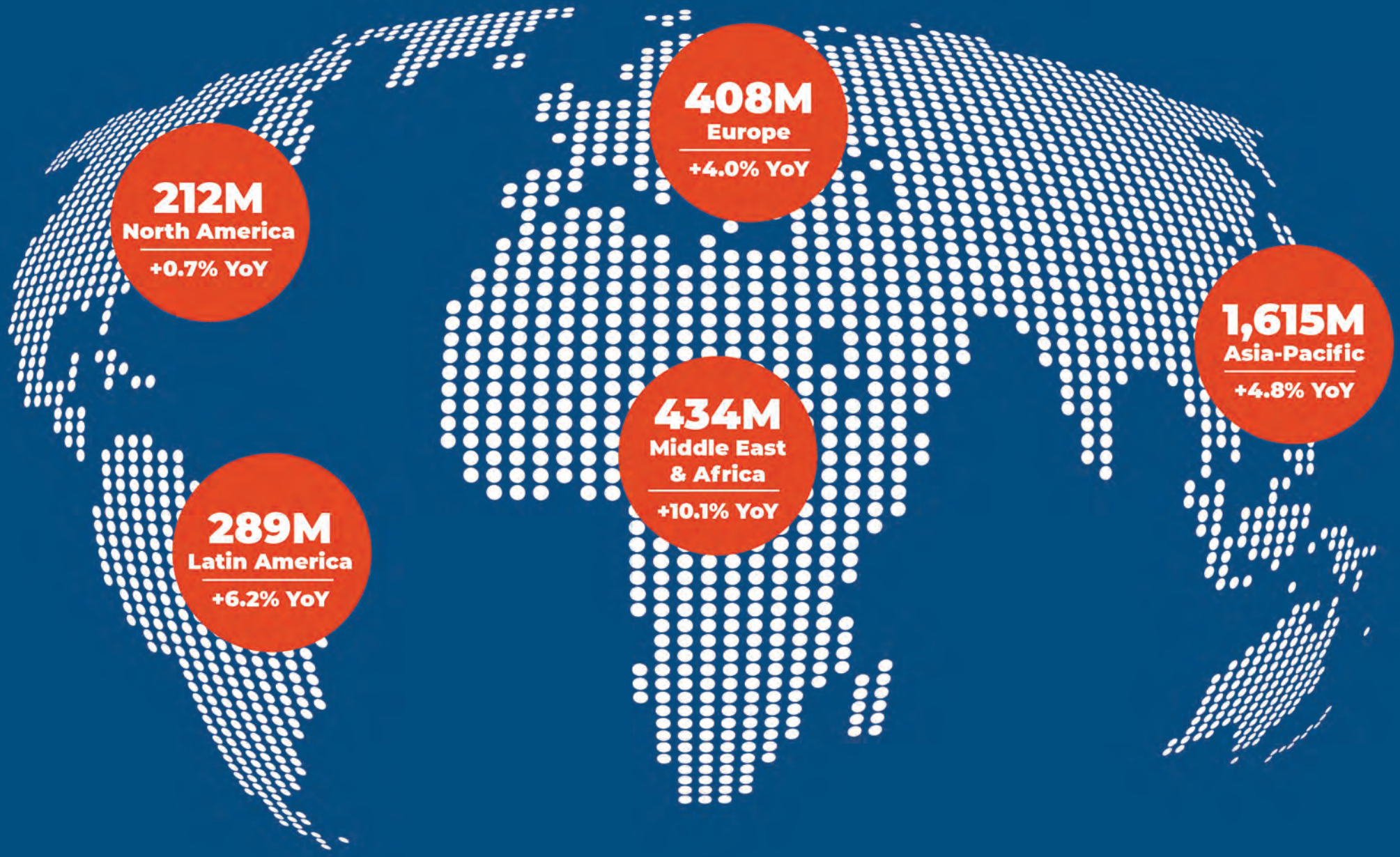
II. THE ATLANTIC COUNCIL AND VR

The Atlantic Council is one of the world's leading foreign affairs think tanks. Founded in 1961 to support the transatlantic alliance, the Atlantic Council has, over time, grown to encompass a global footprint, in both geographic and thematic senses. The Council routinely engages on global environmental challenges, convening world leaders to discuss climate-related challenges and producing thought pieces and policy briefs—reports, issue papers, and blog posts—on how best to solve climate change.

The Adrienne Arsht-Rockefeller Foundation Resilience Center (Arsht-Rock) is pushing the outer boundaries of what a think tank does and how it goes about doing it, with working with the massive gaming industry to combat climate change as one example. Gaming, among the most common activities in the world (more than three billion people worldwide are now "gamers"), is a useful tool for delivering socially and environmentally valuable content and actionable messaging to a mass audience.[3] Over the past several years, the Center has built productive, focused relationships with game development companies and experts in gaming fields, including simulation, visualization, animation, visual effects, sound engineering, and more.

[3] "Number of video gamers worldwide, by region," Statista, September 7, 2021, https://www.statista.com/statistics/293304/number-video-gamers/#:~:text=In%20total%2C%20there%20were%20an,billion%20gamers%20across%20the%20globe.

3.0 Billion Gamers Worldwide in 2021



Source: Newzoo | Global Games Market Report | June 2021
newzoo.com/globalgamesreport

VR is among the most powerful gaming vehicles for delivering messaging and actionable guidance about addressing climate change, which is why Arsht-Rock is building a program of work focused on VR and climate resilience action.

This report resulted from a one-year VR feasibility study led by the Council's Arsht-Rock Resilience Center and the Scowcroft Center for Strategy and Security. The study was intended to be the first step in a multiyear effort featuring VR as a tool to combat climate change.

Photo by Mathias Reding on Unsplash.

The yearlong pilot study yielded three products: this report, which examines VR's potential as a tool for combating and adapting to climate change; a technical paper outlining practicalities involved in building a climate-focused VR experience; and a VR prototype. To develop them, we created a core project team drawn from the Resilience Center's staff and nonresident fellows, including several from within the gaming industry, and the Scowcroft Center's strategic foresight staff. Over one year, the core project team consulted with an outside expert group, consisting of VR professionals from within the gaming industry, climate scientists, psychologists, a climate psychiatrist, marketing professionals, city planners, and climate risk specialists, and also drew additional evidence from desk research.

Our long-term goal is to develop a full VR experience focusing on climate change for use by current and future world leaders. We intend to place our VR experience in front of all those who attend apex global policymaking and business forums such as G7 or G20 meetings, UNFCCC Conference of Parties (COPs), the Munich Security Conference or the Davos Global Leadership Summit. We intend to make our VR experience available to all those who create or influence climate, development or conservation policy and related awareness-raising, including: heads of state (and advisors); national ministers (and advisors); national legislators (and advisors); the most senior officials within multilateral and supranational institutions, e.g., the European Union, the United Nations system, and the major international development banks such as the World Bank and International Monetary Fund; senior executives within the world's largest corporations, foundations, and non-governmental organizations; reporters and influencers from within the world's print, online, and television media; and senior officials from within major civil society organizations such as philanthropies.

III. THE PAST, PRESENT, AND FUTURE OF VR

Although VR has been in development for decades, there is much excitement now because VR finally can deliver what its advocates long have promised. VR's power derives from a set of sophisticated technologies working in unison to create an alternative or "virtual" reality that can be so convincing to the player that they become detached—temporarily at least—from the real, physical world.[4]

Briefly, VR should be distinguished from both two-dimensional video games and AR. In two-dimensional video games, the player engages on a separated screen, which in turn means they never leave the real setting in which they are playing. This contrasts with VR, the goal of which is to fully immerse the player in an environment that is as much divorced from their real setting as possible. AR is closer to VR than are two-dimensional video games, with AR being a kind of bridge between the virtual and the real. AR overlays digital information (images, text, etc.) onto the real world, via smartphone-based apps and—eventually—eyeglass-like devices. VR and AR are compared in Box 2, and a longer technical treatise on AR is provided in Appendix 3.

[4] Iffat Mai, "What's your reality? A VR primer," Building Design + Construction, December 8, 2016, https://www.bdcnetwork.com/blog/whats-your-reality-vr-primer.

The Stanford Ocean Acidification Experience
https://store.steampowered.com/app/409020/The_Stanford_Ocean_Acidification_Experience

COMPARING VR WITH AR

BOX 2

VR and AR provide two different types of experiences with different purposes and utilizing different technologies. Whereas VR is highly immersive, attempting to replace stimuli that the player experiences in the real world with those from a virtual one, AR is a kind of bridge between the virtual and the real. AR overlays digital elements onto real images from the player's physical location, relying on geolocation to pair the real and the virtual. Whereas VR takes the player out of the real world and puts them into a virtual one, AR augments how a person navigates the real physical world. Mixed reality (MR) is a closely related term that refers to "the co-existence and interaction of real-world and virtual objects," and can be considered a subset of AR.[a]

There are numerous AR applications that run on smartphones. The *Pokémon Go* craze of 2016 is an apt example, an AR gaming phenomenon with hundreds of millions of downloads. In this game, players engaged the *Pokémon Go* smartphone app to pursue beloved digital characters overlaid against the real physical world. A player's core task was to travel through the real world chasing after the digital characters in the hope of adding to their *Pokémon* collection.[b]

[a] "What is XR vs AR vs VR vs MR?," VR direct, May 21, 2021, https://www.vrdirect.com/blog/vr-news/what-is-xr-vs-ar-vs-vr-vs-mr/.

[b] Andrew Webster, "Pokémon Go's wild first year: a timeline," The Verge, July 6, 2017, https://www.theverge.com/2017/7/6/15888210/pokemon-go-one-year-anniversary-timeline.

[c] For a summary of AR's divergent definitions, as well as provision of a consensus definition, see Niek Zuidhof, "Defining smart glasses: A rapid review of state-of-the-art perspectives and future challenges from a social sciences' perspective," Augmented Human Research 6, 15 (2021), https://link.springer.com/article/10.1007/s41133-021-00053-3.

The vision for AR extends beyond such smartphone applications. The goal is to create AR glasses that offer seamless interaction with the everyday "real" world. AR glasses are eyeglass-like devices that relay digital information to the player in real time as they transit the actual physical environment.[c] There is significant private sector investment behind this concept. Big Tech firms, including Google, Apple, Meta, Magic Leap, Microsoft, Qualcomm, and Sony are racing to develop and perfect affordable and capable AR glasses. The technology is close to the ideal but not quite there. Microsoft's Hololens 2, on the market now, resembles a cross between a large HMD and a pair of eyeglasses. Its functionality is best indoors, rather than outdoors, and it is expensive for a typical person, starting around $3500.[d] Apple's much-anticipated AR glasses, believed to be yet some way off, should be a pair of lightweight eyeglasses that would be synced to the wearer's iPhone, which would transmit data (texts, emails, app visuals, etc.) to the wearer's field of vision.[e]

The upshot is that both AR and VR have enormous potential for influencing how people, including leaders, see and understand the world, thus for shaping their views about the planet's changing climate. In this respect, the two technologies should be viewed as complementary rather than oppositional. Moreover, the boundaries between the two technologies already are blurring. Meta's concept of and vision for its own version of the "metaverse," as an example, almost certainly will utilize both AR and VR elements, simultaneously or sequentially, to engage its consumers.[f]

[d] Lisa Eadicicco, "The race to build AR glasses is heating up, and Samsung is surprisingly quiet," cnet, January 17 2022, https://www.cnet.com/tech/mobile/the-race-to-build-ar-glasses-is-heating-up-and-samsung-is-surprisingly-quiet/; Alex Heath, "Google is building an AR headset," The Verge, January 20, 2022, https://www.theverge.com/2022/1/20/22892152/google-project-iris-ar-headset-2024. For a review of Microsoft's Hololens 2, see "HoloLens 2 Review: The Best In Class For AR, But…," The Ghost Howls, August 12, 2021, https://skarredghost.com/2021/08/12/hololens-2-review/. Pricing can be found at "Hololens 2," Microsoft, https://www.microsoft.com/en-us/hololens/buy.

[e] Kate Kozuch, "Apple Glasses: Everything we've heard so far," Tom's Guide, June 13, 2022, https://www.tomsguide.com/news/apple-glasses.

[f] Stefan Brambilla Hall and Moritz Baier-Lentz, "3 technologies that will shape the future of the metaverse – and the human experience," World Economic Forum, February 7, 2022, https://www.weforum.org/agenda/2022/02/future-of-the-metaverse-vr-ar-and-brain-computer/.

Photo by Mika Baumeister on Unsplash.

A. VR'S PAST

Although VR can trace an intellectual path back to the nineteenth century, VR's technical development originated in the 1950s and 1960s.[5] The first rudimentary HMDs were created in the early 1960s, for both the cinema and the United States military, which tied movements of the player's head to movements of remote cameras to peer into dangerous situations from the player's remote (and presumably safe) location. In 1965, a DARPA (Defense Advanced Research Projects Agency) scientist named Ivan Sutherland wrote about how a "display connected to a digital computer [would give] us a chance to gain familiarity with concepts not realizable in the physical world" and therefore provide "a looking glass into a mathematical wonderland." He predicted a day when computers could "sense the positions of almost any of our body muscles" and even to "sense and interpret eye motion data."[6] Sutherland was one of the first to articulate a vision of how digital computation, then in its infancy, might eventually be powerful enough to enable the creation of what we now understand as virtual worlds, in his parlance a "mathematical wonderland."[7]

From the 1970s to the early 1990s, the military, NASA, major corporations, universities, and technology startups steadily developed VR-related technologies, including the first primitive simulated spaces, improved HMDs, and the first VR-enabled gloves. Commercial development followed not long after. The first VR arcade games were developed in the early 1990s, and in 1995, Nintendo created the first commercial VR application, the *Virtual Boy* system, which failed due to poor graphical fidelity, poor software support, and low comfort.

Yet VR continued to benefit from rapidly increasing computing power. By the 2010s, VR was ready for successful commercial application. In a now-classic Silicon Valley success story, in 2010 the teenaged Palmer Luckey created the *Oculus Rift* prototype,

[5] Unless otherwise cited, this historical summary is drawn from Dom Barnard, "History of VR - timeline of events and tech development," Virtual Speech, August 6, 2019, https://virtualspeech.com/blog/history-of-vr.

[6] Ivan E. Sutherland, "The ultimate display," Proceedings of IFIP Congress (1965), pp. 506-508, http://worrydream.com/refs/Sutherland%20-%20The%20Ultimate%20Display.pdf.

[7] Sutherland, "ultimate".

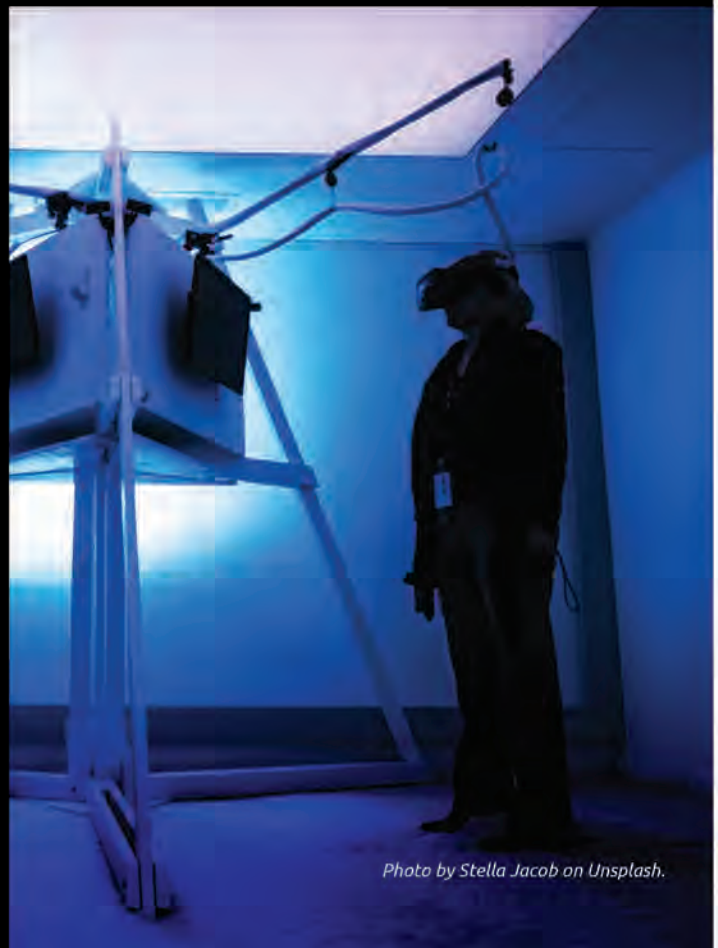


Photo by Stella Jacob on Unsplash.

in 2012 he attracted $2.3 million in crowdsourced (Kickstarter) funding, and in 2014 he sold his Oculus startup company to Facebook (now Meta) for $2 billion. This acquisition was just the beginning of massively accelerated consumer VR, with Google, Samsung, Amazon, Apple, HTC, and Sony among the companies bringing consumer VR devices to market during the 2010s.

B. VR'S PRESENT

Now, at the onset of the 2020s, the VR space is characterized by high technical sophistication, a massive and growing consumer market, and enormous corporate investment. The global VR market is worth tens of billions of dollars and has hundreds of millions of players around the world (Box 1).

Intense realism is a key distinguishing feature of today's VR experiences, in turn the central component of VR's current value proposition, which is an experience so compelling that the player believes they inhabit an alternative reality. Over the past decade, VR's technical elements have progressed rapidly. These elements are summarized below (for a longer treatment, see Appendix 2).

- **GRAPHICAL FIDELITY**: Some VR systems, especially tethered systems (where the HMD is connected to a high-powered gaming computer), are now reaching a point where many players find it difficult to distinguish the virtual from the real. Non-tethered HMDs have less fidelity but still provide a stunning visual experience.[8]

- **AUDIO QUALITY**: Contemporary audio in VR closely approximates directionality in real life. This can intensify the connection a VR player feels with the virtual environment. Although the player often does not consider audio as part of their conscious experience while in VR, high audio quality contributes greatly to the power of the VR experience.[9]

Photo by Christine Sanduon Unsplash.

[8] For examples of latest-generation untethered and tethered systems, respectively, see "Quest 2," Meta Quest, https://www.oculus.com/quest-2/, and "Half-Life: Alyx," Steam, https://store.steampowered.com/app/546560/HalfLife_Alyx/.

[9] Pontus Larsson, Daniel Vastfjall, and Mendel Kleiner, "Better Presence and Performance in Virtual Environments by Improved Binaural Sound Rendering," 22nd International Conference: Virtual, Synthetic, and Entertainment Audio (June 2002), Paper 000228; Pontus Larsson, Daniel Vastfjall, and Pierre Olsson, "When what you hear is what you see: Presence and auditory-visual integration in virtual environments," Presence 2007 (January 2007), https://www.researchgate.net/publication/228640443_When_what_you_hear_is_what_you_see_Presence_and_auditory-visual_integration_in_virtual_environments.

- **OBJECT MOTION:** Sensors can be attached to many real-world objects so that a computer can link the object's motion in the real physical environment with a corresponding motion in the VR experience. Movement is facilitated by increasingly capable and lightweight hand-tracking and haptic feedback devices.[10] Full-body trackers now exist that enable players' body movements to be mimicked in the VR experience (via their avatar), adding an important dimension to players' social interaction with other players.[11]

- **LOCOMOTION:** Locomotion, which in a VR setting refers to the digital replication of the player's walking and running, is technically challenging but currently available through sensors and omnidirectional treadmills.[12]

- **SCENT AND TASTE:** Incorporation of these two senses into the VR experience is the least developed, as they are the hardest to translate into digital form given that these senses utilize molecular receptors in the nose and mouth.[13] Scents can be integrated into VR experiences using oils, but taste has proven even more difficult to replicate.[14]

[10] Go Touch VR, a French company, has developed a three-fingered haptics device that gives the player the impression of real handheld manipulation of virtual objects, for example buttons and sliding doors. See https://www.gotouchvr.com/copy-of-technology-devices-1. Similarly, VIVE offers trackers that can be attached to the body (legs, arms, etc.) and other objects such as rackets for sports games, thereby turning ordinary items into VR-enabled devices. See https://www.vive.com/us/accessory/tracker3/.

[11] See, for example, VR Chat: https://hello.vrchat.com/. For a discussion, see Guilherme Gonçalves et al., "Evaluation of the impact of different levels of self-representation and body tracking on the sense of presence and embodiment in immersive VR," Virtual Reality 26 (2022), p. 13, https://doi.org/10.1007/s10055-021-00530-5.

[12] Ivy Wigmore, "VR Locomotion," TechTarget, https://www.techtarget.com/whatis/definition/VR-locomotion-virtual-reality-locomotion.

[13] See, e.g., Daniel Kolitz, "Is there VR for senses other than sight?," Gizmodo, April 9, 2021, https://www.gizmodo.com.au/2021/04/is-there-vr-for-senses-other-than-sight/; Emily Matchar, "Using electric currents to fool ourselves into tasting something we're not," Smithsonian, August 15, 2018, https://www.smithsonianmag.com/innovation/using-electric-currents-to-fool-ourselves-into-tasting-something-were-not-180970005/.

[14] One company, VAQSO, has created an HMD-mounted scent device. See https://vaqso.com/#API.

Photo by XR Expo on Unsplash.

C. VR'S FUTURE

Commercial interests clearly are driving VR development forward, with large technology firms, including Meta, Valve, Sony, and HTC, competing for a much larger future VR consumer market. Meta, HTC, Valve, and other firms are investing in more capable headsets that will contain higher-end graphics, improved sound and tracking, and greater comfort.[15] As is true in other areas of profitable consumer product development, firms are pushing the technological curve. An analogue is the post-2007 evolution of the smart phone, when Big Tech companies catalyzed the swift market penetration of smart phones around the world.[16]

For the future, the important questions involve impacts on individuals and society if more people use VR for daily tasks such as social interaction, shopping, and working in addition to gaming. The question is whether this immersion will be positive, negative, or both. Critics argue that greater exposure to virtual worlds will further alienate people from physical reality more than they already are.[17] Yet future versions of VR also will offer players the ability to create a shared social space and find meaning.[18]

Whether people end up spending significantly more time in virtual worlds remains to be seen. There is an upper limit to how much time per day a person can spend in VR owing to psychological constraints. Few people are capable of spending long periods of time separated from reality owing, as one critic phrases it, to "the deeply human aversion to feeling cut off from your surroundings."[19] Even in this scenario, VR would remain an important tool, given that VR systems should be able to deliver ever-more powerful, even photorealistic, depictions of alternative worlds.

[15] Meta's next generation wireless headset, dubbed Project Cambria, should include advanced eye and facial tracking capabilities in addition to integration of some AR-capable features. See Gerald Lynch, "Project Cambria: All there is to know about Meta's rumored Oculus Quest Pro," TechRadar, February 27, 2022, https://www.techradar.com/news/oculus-quest-pro-project-cambria. In 2021, HTC introduced the VIVE Pro 2, an upgrade to its 2018 Pro model containing higher-end graphics, improved sound, and facial tracking. See James Vincent, "HTC unveils new Vive Pro 2 with 5K resolution display and 120Hz refresh rate," The Verge, May 11, 2021, https://www.theverge.com/2021/5/11/22428603/htc-vive-pro-2-release-date-pre-order-price-specs. Valve's Index is a PC-tethered VR system with a reputation for high visual fidelity and accurate motion tracking, while Sony's forthcoming PSVR 2 for its PlayStation also earning early plaudits for its expected higher visual resolution, comfort, eye tracking, and more. See Gerald Lynch, "Valve Index review: The pinnacle of VR technology," Live Science, March 21, 2022, https://www.livescience.com/valve-index-review; Scott Stein, "PlayStation VR 2 design revealed: PS5 players, get excited," cnet, February 23, 2022, https://www.cnet.com/tech/gaming/playstation-vr-2-ps5-everything-we-know-so-far/.

[16] Although it did not invent the smart phone, Apple's 2007 introduction of the iPhone revolutionized the market. See Tuan C. Nguyen, "The brief history of smartphones," ThoughtCo., January 30, 2021, https://www.thoughtco.com/history-of-smartphones-4096585.

[17] See, e.g., Jack Butler, "Behold the metaverse," The National Review, January 21, 2022, https://www.nationalreview.com/corner/behold-the-metaverse/.

[18] See, e.g. Bryan Lufkin, "How online gaming has become a social lifeline," BBC News, December 16, 2020.

[19] For a strongly held articulation of this view, see Louis Rosenberg, "There are two kinds of Metaverse. Only one will inherit the Earth," Big Think, January 11, 2022, https://bigthink.com/the-future/metaverse-augmented-virtual-reality/.

IV. VR AND THE MIND

Climate advocates' excitement about VR is based upon how the mind perceives stimuli in a virtual setting and, by extension, how it shapes perceptions after the virtual experience is over. This section addresses how VR impacts the mind and hypothesizes how such impacts might induce change in the real world.

A. VR AND THE PERCEPTION OF REALITY

Perhaps the most critical difference separating VR from standard two-dimensional video games is VR's extraordinarily powerful effects on the player's perception of reality. *Immersion* and *presence* are two similar terms that together refer to how VR shapes the player's perception that the experience they are having is real. Immersion refers to how effective the VR experience is at tricking the player's senses. Immersion is all about technical mastery of the virtual space. Presence refers more to how engaged the player feels in the VR experience, through its storyline, the player's interactions with other characters, the player's avatar, and more.

VR creates awe when it delivers both high immersion and high presence. In such VR experiences, players can temporarily forget that that they are even in a virtual world, such is the visceral impact of the best-designed of these experiences. Indeed, VR's potential power over the player's mental, emotional, and physical states is so great that a theoretical end state is a *Matrix*-like experience, meaning a simulation of reality that mimics the real world down to the most granular details. "A fully immersive VR

[20] "The difference between presence and immersion," The Ghost Howls, November 9, 2016, https://skarredghost.com/2016/11/09/the-difference-between-presence-and-immersion/.

"A fully immersive VR world would be able to encompass every single sense and interact directly with the brain and nervous system," one observer writes. "In some sense it could even be a replacement for consensus reality.

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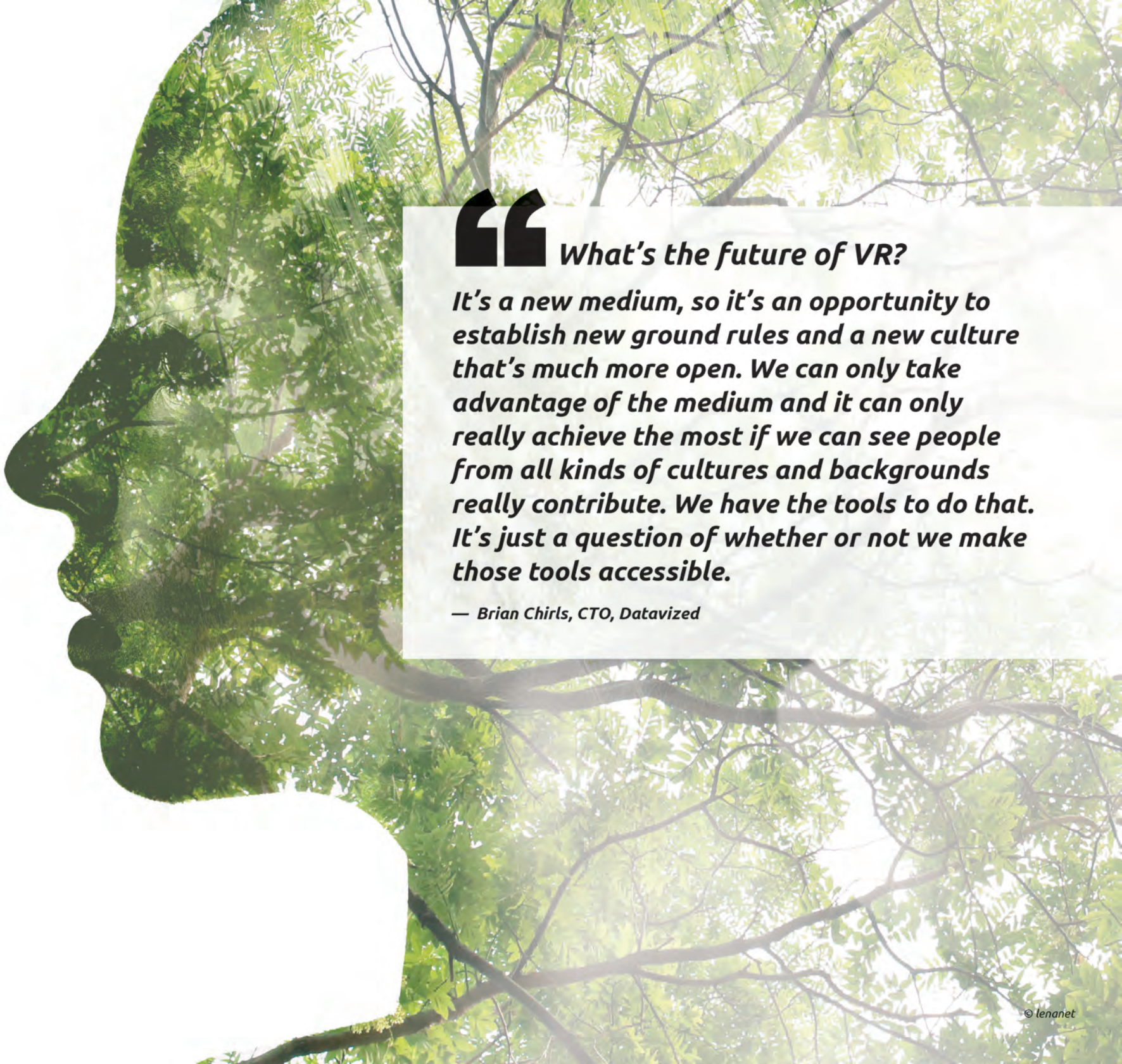

What's the future of VR?

It's a new medium, so it's an opportunity to establish new ground rules and a new culture that's much more open. We can only take advantage of the medium and it can only really achieve the most if we can see people from all kinds of cultures and backgrounds really contribute. We have the tools to do that. It's just a question of whether or not we make those tools accessible.

— Brian Chirls, CTO, Datavized

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world would be able to encompass every single sense and interact directly with the brain and nervous system," one observer writes. "In some sense it could even be a replacement for consensus reality."[21]

Research does show that there are psychological limits to the use of VR to mimic reality. In VR, players can be overwhelmed by too much information and stimuli, which leads to difficulties processing information, internalizing key messages, completing core tasks, and more.[22] VR imposes these higher "cognitive loads" because of the processing requirements placed on the brain, resulting from the sensory inputs from the HMD and haptic devices (handheld and wearable devices, vibrating platforms, heat lamps, fans, etc.).[23] As a general rule, players should be able to take what they need from the experience without resorting to pre- and post-experience content. The challenge is to provide enough stimuli and information within the VR experience while avoiding overload.

[21] Mike Colagrossi, "What would it take to create a fully immersive virtual reality?," Big Think, January 7, 2019, https://bigthink.com/the-present/what-would-it-take-to-create-a-fully-immersive-virtual-reality/.

[22] For a short and useful summary, see Kathryn Whitenton, "Minimize cognitive load to maximize usability," Nielson Norman Group, December 22, 2013, https://www.nngroup.com/articles/minimize-cognitive-load/.

[23] Matthew Barnidge et al., "The effects of virtual reality news on learning about climate change," Mass Communication and Society (2021), DOI: 10.1080/15205436.2021.1925300. VR developers have devised strategies to reduce cognitive load, for example sequencing the introduction of new manipulative elements rather than introducing many at once. See Adrienne Hunter, "Reducing cognitive load in VR," Virtual Reality Pop, August 30, 2016, https://virtualrealitypop.com/reducing-cognitive-load-in-vr-d922ef8c6876.

VR sickness is a related problem, which can happen when the mind perceives that the body is moving in VR (walking or falling, for example) when the player's body is in fact at rest. This problem is compounded both by the intensity of the VR experience and by processing delays, the lags that can occur between when the player moves in VR and when the VR system responds.[24] A rule of thumb is to keep VR experiences short, perhaps ten minutes or less, to minimize the odds of sickness.[25]

Yet these caveats notwithstanding, today's VR experiences in fact deliver intense experiences. Although it may not be possible to ever mimic the full range and depth of reality as in the Matrix films, the technology's power to inspire, to induce awe in the player, to create a vivid sensory experience, and ultimately to deliver a compelling emotional experience, is extraordinary.

B. A THEORY OF MIND FOR VR

Although psychologists understand the VR-mind nexus differently, one compelling theory of mind in the VR context is known as self-determination theory (SDT). According to one review, SDT is "centered on the basic psychological needs of autonomy, competence, and relatedness and their necessary role in self-determined motivation, well-being, and growth."[26] Autonomy refers to the human need for self-direction, to determine one's path in the world. Competence refers to peoples' need to feel successful in navigating the world. *Relatedness* refers to how people need to feel connected with other people in communities that they value.[27]

VR experiences should be built around these three motivations because each is fundamental to the human experience. For example, if autonomy means that players want to possess agency and competence that they want to be successful, developers should build meaningful choices and

"The technology's power to inspire, to induce awe in the player, to create a vivid sensory experience, and ultimately to deliver a compelling emotional experience, is extraordinary.

[26] Lisa Legault, "Self-Determination Theory," in V. Zeigler-Hill and T.K. Shackelford (eds.), Encyclopedia of Personality and Individual Differences (New York: Springer International Publishing AG, 2017), DOI 10.1007/978-3-319-28099-8_1162-1, p. 1.

[27] Legault 2017, p. 2.

coherent narrative structures into the VR experience.[28] Game mechanics that provide feedback and progression, perhaps augmented by tutorials, can motivate players by increasing their comfort levels while going through the VR experience, in turn increasing their sense of autonomy and competence.[29] Satisfying the three needs more strongly predicts players' enjoyment with the experience, reduces the burdens associated with cognitive load, and enhances their belief that they are actors in the VR experience rather than just observers.[30]

Moreover, these psychological considerations matter because VR experiences that are personally meaningful to the player should successfully impact how the player feels not only about the VR experience itself but also about the experience's content – its substantive message and lessons.[31] The key is to have the substance that the developers build into the game – the messaging about climate change that is "external" to the player – reinforce the player's "internal" desire for autonomy, competence, and relatedness.[32]

As discussed in Box 3, the reader should note that VR experiences should be tailored as much as possible to the specific types of motivations that players might bring with them to the experience.

[28] Scott Rigby, "The Freedom Fallacy: Understanding 'Player Autonomy' in Game Design," GDC Vault (2017), at 12:25–16:00, https://www.gdcvault.com/play/1024043/The-Freedom-Fallacy-Understanding-Player.

[29] Jean-Nicolas Proulx, Margarida Romero, and Sylvester Arnab, "Learning mechanics and game mechanics under the perspective of self-determination theory to foster motivation in digital game based learning," Simulation & Gaming (2016), https://journals.sagepub.com/doi/abs/10.1177/1046878116674399.

[30] Ryan, Rigby, and Przybylski, "motivational."

[31] Richard M. Ryan, C. Scott Rigby, and Andrew Przybylski, "The motivational pull of video games: A self-determination theory approach," Motivation and Emotion 30 (2006), pp. 344-360, https://link.springer.com/article/10.1007/s11031-006-9051-8.

[32] Lisa Legault, "Intrinsic and Extrinsic Motivation," in V. Zeigler-Hill and T.K. Shackelford (eds.), Encyclopedia of Personality and Individual Differences (New York: Springer International Publishing AG, 2016), DOI 10.1007/978-3-319-28099-8_1139-1.

Photo by Alfred Aloushy on Unsplash.

DIVERSITY OF PLAYER MOTIVES

BOX 3

The VR consumer audience is enormous and diverse. Players bring to the VR experience their varying interests, cultural perspectives, preferences, ages, genders, educational levels, nationalities, ethnicities, socioeconomic backgrounds, and more. This creates challenges for tailoring VR experiences to the attributes of different types of players.

One market research firm in the gaming industry, Quantic Foundry, has collected data from hundreds of thousands of VR players, shedding light on their motivations.[a] Its data indicates that games featuring destruction (wargames, etc.) and excitement are more attractive to young men than young women, as might be expected. However, both genders reduce their interest significantly in these features as they get older. Quantic Foundry's Nick Yee draws the conclusion that age is a far more important variable than gender. Players consistently reduce their interest in these specific sub-categories as they age, with males' interest falling faster than females'. By age 55, the gender gap has closed entirely.[b]

An interesting wrinkle is that the Quantic Foundry data indicates that older people use VR more frequently than younger ones, perhaps owing to the higher cost of purchasing VR systems. Regardless of the reason, the firm's data suggest that as the VR market skews older, self-motivation for playing certain types of games is less driven by gender.[c]

The upshot is that we should be wary of stereotyping VR users. Yee writes that in contrast to the stereotype that gamers seek escapism from their own lives, "games can be seen as a kind of identity management tool; gamers gravitate towards the gameplay that aligns with their core personality traits."[d]

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a Quantic Foundry, Gamer Motivation Model. Reference Sheets & Details (V2), undated (ca. 2019), https://quanticfoundry.com/wp-content/uploads/2019/04/Gamer-Motivation-Model-Reference.pdf.

b Nick Yee, "What motivates gamers?," Medium, September 23, 2019, https://medium.com/ironsource-levelup/what-motivates-gamers-ccbffe9180c0.

c Nick Yee, "Older gamers who can afford VR tend to care less about the gaming motivations linked to VR adoption," Quantic Foundry, March 1, 2019, https://quanticfoundry.com/2019/03/01/vr-adoption/.

d Yee, "motivates."

Photo by James Donaldson on Unsplash.

V. VR FOR CLIMATE LEADERSHIP

As stated in the Introduction, numerous VR applications have been developed for raising awareness about and combating environmental degradation, including climate change. The aforementioned Tree is an example of a VR experience designed to raise awareness about deforestation in the tropics through increasing empathy with other beings besides humans. In the Tree case, the developers raised players' empathy with the kapok tree through reliance on something known as the Proteus Effect, a phenomenon referring to how players take on the characteristics of the avatar that is assigned to them in a game (see Box 4).

> ***"People's identities in VR can be malleable—protean—as they can take on the characteristics of the avatar that is given to them.***

Photo by Eyoel Kahssayon Unsplash.

THE PROTEUS EFFECT

BOX 4

People tend to think and behave differently when assigned an avatar in VR. The Proteus Effect describes this phenomenon, which occurs when players "adhere to a new identity that is inferred from their avatars."[a] People's identities in VR can be malleable—protean—as they can take on the characteristics of the avatar that is given to them. This allows the player to explore actions they may not normally take in real life, giving them the safety to experiment and explore.

Although other types of experiences—films, television shows, video games, etc.—also give people a perspective on how other humans and non-humans see the world, VR might be the most powerful at doing so. VR's immersive qualities enable the player to virtually embody another person or being and increases the player's empathy with their avatar.[b]

VR can be used to players' environmental awareness, including climate change, through building empathy via avatars. Placing players into a first-person experience of a plant, animal, or another human raises their empathy with that perspective and by extension with that person or being.[c] Translated into a climate-focused VR experience, a player who experiences the perspective of someone or something living through a climate-driven scenario (a fire, flood, heatwave, or other disaster, for example) might alter their thinking about climate change and perhaps their willingness to engage more constructively on the issue.

[a] Nick Yee & Jeremy Bailenson, "The Proteus Effect: The effect of transformed self-representation on behavior," Human Communication Research 271 (2007), p. 271.

[b] A 2018 study, for example, that placed male domestic violence offenders in the virtual bodies of female victims found that, after the VR experience, the offenders had a greater ability to recognize fear in female faces and a reduction in satisfaction when seeing such fear in a female face. See S. Seinfeld et al., "Offenders become the victim in virtual reality: Impact of changing perspective in domestic violence," Scientific Reports 8, 2692 (2018), https://doi.org/10.1038/s41598-018-19987-7.

[c] See, e.g., Sun Joo (Grace) Ahn et al., "Experiencing nature: Embodying animals in immersive virtual environments increases inclusion of nature in self and involvement with nature," Journal of Computer-Mediated Communication (2016), https://www.stanfordvr.com/mm/2016/08/ahn-jcmc-experiencing-nature.pdf.

Photo by Jeremy Goldberg on Unsplash.

Organizations have used VR to deliver compelling environmental messages in other ways. For example, in 2016, Stanford University's Virtual Human Interaction Lab developed the *Stanford Ocean Acidification Experience (SOAE)*, which focused on conveying a scientific problem (ocean acidification) through tracing carbon dioxide (CO_2) molecules from automobile tailpipe to the ocean. In SOAE, players became scientists measuring coral reef health. Much of the focus in SOAE was on education, given the poorly understood nature of ocean acidification.[33]

Other VR experiences are just as creative. In 2018, the VR studio Condition One released a four-part VR film series, *This is Climate Change*, that used 3D stereoscopic techniques to convey stunning imagery of a planet under severe distress. The film's four parts, titled *Fire, Famine, Feast*, and *Melting Ice* stressed the spread of wildfires, drought and famine, deforestation, and melting glaciers respectively.[34]

[33] "The Stanford Ocean Acidification Experience," Stanford University Virtual Human Interaction Lab, https://stanfordvr.com/soae/. For an academic analysis of impacts on educators who experienced SOAE, see Géraldine Fauville et al., "Participatory research on using virtual reality to teach ocean acidification: A study in the marine education community," Environmental Education Research 27:2 (2021), pp. 254-278, DOI: 10.1080/13504622.2020.1803797.

[34] Danfung Dennis and Eric Strauss, "This is Climate Change," MIT, 2018, https://docubase.mit.edu/project/this-is-climate-change/; D. Hardawar, "In 'This is Climate Change,' you can't look away from the destruction," Engadget, April 22, 2018, https://www.engadget.com/2018-04-22-this-is-climate-change-vr.html.

Not to be outdone, The Hydrous, a nonprofit ocean science organization, developed *IMMERSE*, a 360-degree VR film that takes the viewer on a virtual dive of Palau's stunning coral reefs. Debuted at the International Ocean Film Festival in 2019, the IMMERSE VR experience portrays the extraordinary beauty of Palau's reefs so viscerally that the player feels, not just views, the majesty of a world they have never seen. The Hydrous team's goal was to build a "universal ocean empathy" among the people who went through the VR experience, which would translate into their raised awareness and heightened willingness to act to protect the world's oceans and reefs.[35] Realizing that its VR experience should be brought to as many people as possible, The Hydrous built a supporting base of digital and physical products: a sleek digital website and brochure that relays IMMERSE's beauty; a "Learning Expedition Kit" for students, consisting of lessons, activity cards, a 3D printed coral model, a cardboard VR viewer, and a lapel pin; auxiliary video lessons from ocean scientists; and more.[36]

These are but a few of the many VR experiences focusing on the environment and climate. For a longer review, see Appendix 1.

A. LEADERSHIP AS A CATEGORY

VR experiences generally are designed for broad audiences. The SOAE developers, for example, intended for SOAE to have widespread educational impact.[37] Likewise for *In My Shoes*, a more recent oceans-focused VR experience developed by the environmental non-profit Sachamama. The organization works with social influencers and celebrities to raise awareness about *In My Shoes* and drive traffic toward its website, where the VR experience can be downloaded.[38]

[35] Megan Alldridge and Stefanie Blendis, "A marine biologist is using virtual reality to bring people closer to the ocean," CNN, February 19, 2021, https://www.cnn.com/2021/02/18/world/erika-woolsey-vr-dive-hydrous-immerse-spc-intl/index.html.

[36] These resources all can be accessed from The Hydrous homepage at https://thehydro.us/.

[37] According to SOAE's website, although SOAE has been used by "policy makers around the world, including the U.S. Senate and the Palauan National Congress," it also "has been downloaded in over 100 countries and territories." Stanford University Virtual Human Interaction Lab, "Acidification," https://stanfordvr.com/soae/.

[38] Maribel Ramos-Weiner, "Goldenbird creates VR experience with the environmental organization Sachamama of Carlos Zegarra," Produ, October 22, 2021, https://www.produ.com/noticias/eng/goldenbird-creates-vr-experience-with-the-environmental-organization-sachamama-of-carlos-zegarra; "Ocean Initiative," Sachamama, https://sachamama.org/ocean-initiative/; "In My Shoes," https://www.inmyshoes.us/.

Photo by Tom Bixler on Unsplash.

There is nothing incorrect about these marketing strategies. Yet they are not designed for maximum impact on leaders—people who, compared with the general public, have different perspectives on, information about, and face unique challenges with respect to acting on environmental problems, including climate change.

As raised at the outset of this report, leadership as a category is diverse. Leaders are drawn from many quarters across society, for example:

- **BY SECTOR:** Public sector leaders such as politicians and departmental heads or ministers are different actors with different responsibilities compared with executives from the private and nonprofit sectors.

- **BY GEOGRAPHY:** National, supranational, and sub-national categories of leadership have different responsibilities, authorities, and geographic reach. A senior executive from the United Nations has a global portfolio, a prime minister a national one, and a mayor a local one.

- **BY INSTITUTION:** Leaders' portfolios also are institutionally determined. A foreign minister's responsibilities, constraints, authority, and perspectives will differ from those of an energy or environment minister, which in turn will differ from those of an executive from a multinational corporation.

Development teams interested in building a VR experience to shape leaders' perceptions about climate change and drive behavioral change will have to incorporate these considerations into the research design. There is no reason

why a single VR experience cannot impact every leader in the world with a universal appeal if it is well designed and carries a weighty emotional and visceral punch. *IMMERSE* might focus on coral reefs in Palau, but its message really is about protecting all ocean life. Yet design teams will need to realize that universal VR messaging as in *IMMERSE* will necessitate compromising on granular appeals to specific leaders in specific places.

There is no systematic data regarding how many world leaders, however defined, have thus far gone through climate-based VR experiences. However, there is much in the way of individual information about world leaders, including heads of state, who have either publicly gone through a VR experience or endorsed the technology, or both. In 2016, for example, both President Obama and President Xi Jinping openly endorsed VR as a promising technology for raising environmental awareness (Obama) and boosting the knowledge economy (Xi). President Obama lent his voice to a VR film production focusing on America's National Parks, while President Xi stressed VR's importance for innovation.[39] Other current and former heads of state, from Justin Trudeau to Olaf Scholz to Boris Johnson to Lee Hsien Loong, publicly have gone through VR experiences, suggesting a willingness to be seen interacting with the technology (e.g., wearing headsets).[40]

[39] Lucas Matney, "President Obama has his virtual reality debut in new Felix & Paul experience," Tech Crunch, August 25, 2016, https://techcrunch.com/2016/08/25/president-obama-has-his-virtual-reality-debut-in-new-felix-paul-experience/; Jamie Feltham, "Chinese president points to VR as helping establish 'innovative world economy'," Upload VR, September 5, 2016, https://uploadvr.com/chinese-president-vr-b20/.

[40] Several of these current or former heads of state did so while in previous positions. See: "Prime Minister Justin Trudeau tries out virtual reality at Ubisoft Montreal," CBC, 2016, https://www.cbc.ca/player/play/2684433337; "Mayor of Hamburg Olaf Scholz tried the VSI HoloMedicine®," apoQlar, October 18, 2017, https://youtu.be/W0oli1qK6ME; "Boris Johnson experiences dog simulation in Israel," BBC News, November 9, 2015, https://www.bbc.com/news/av/uk-england-london-34768824; Irene Tham, "Google moves to new office to house fast growing team of engineers in Singapore," The Straits Times, November 10, 2016, https://www.straitstimes.com/tech/google-moves-to-new-office-to-house-fast-growing-team-of-engineers-in-singapore#xtor=CS1-10.

Each line represents the average temperature in a year with blue-coloured lines indicating colder temperatures and red indicating warmer.

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https://www.independent.co.uk/climate-change/cop26-climate-graph-warm-planet-b1949745.html


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CBC News
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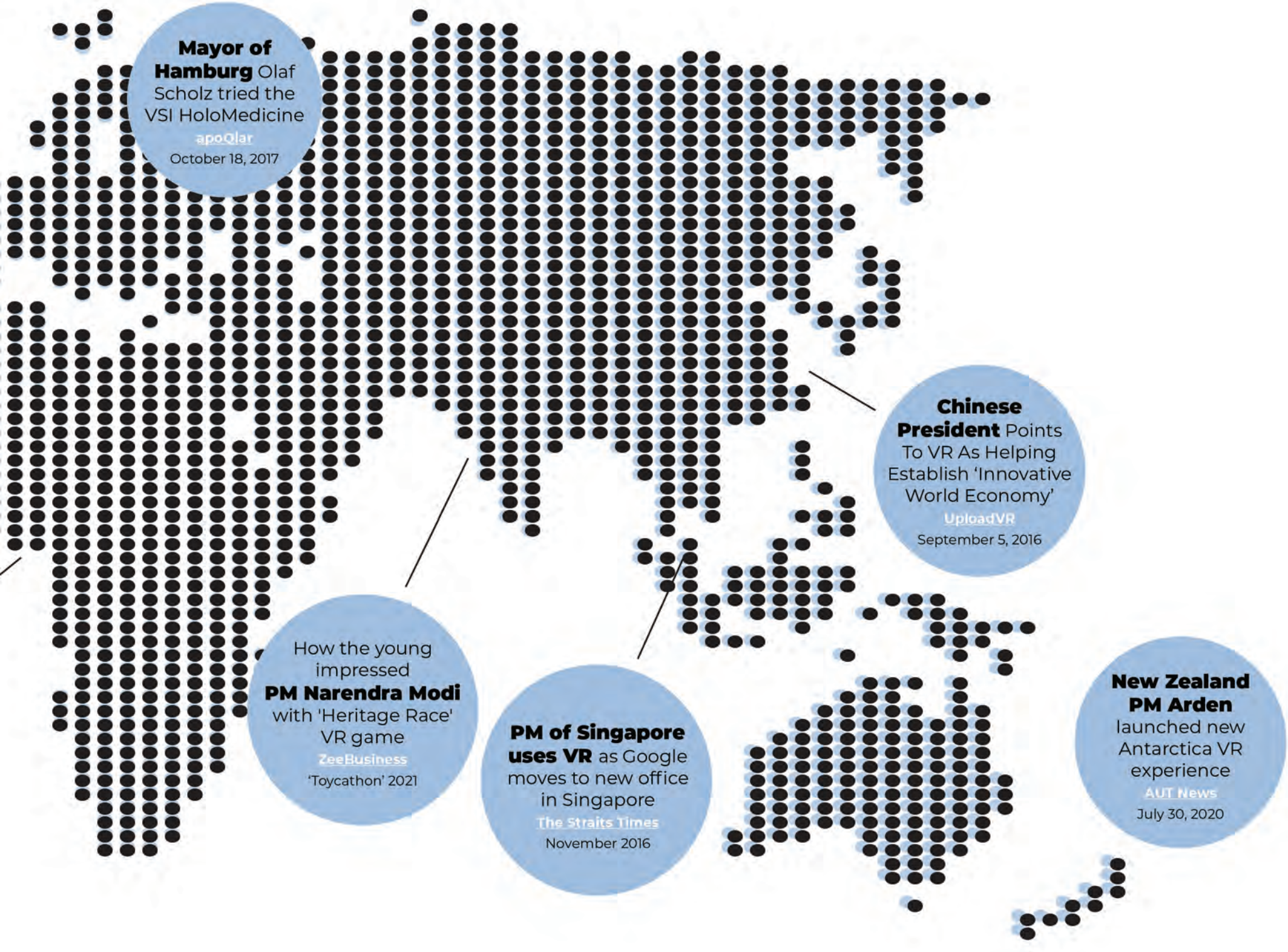
Mayor of Hamburg Olaf Scholz tried the VSI HoloMedicine
apoQlar
October 18, 2017
Chinese President Points To VR As Helping Establish 'Innovative World Economy'
UploadVR
September 5, 2016
How the young impressed **PM Narendra Modi** with 'Heritage Race' VR game
ZeeBusiness
'Toycathon' 2021
PM of Singapore uses VR as Google moves to new office in Singapore
The Straits Times
November 2016
New Zealand PM Arden launched new Antarctica VR experience
AUT News
July 30, 2020

Photo by Mika Baumeister on Unsplash.

B. FACTORS INSPIRING OR INHIBITING CLIMATE LEADERSHIP

Leaders are motivated by factors that are both internal and external to themselves. This mix includes their visions for how they want the world to change in the future, their emotions (hopes and fears about the world now and into the future), their values (ethics and morals about what is right and wrong in the world), any ideological convictions such as where they sit on the right-left spectrum, their religious beliefs, their sense of and commitment to institutional or national purpose, the degree of their exposure to and pressure from external groups, the institutional and legal freedoms or constraints on their policymaking behavior, and of course instrumental factors related to their pursuit of power and career.

We can collapse this diverse complex of factors into two large categories. The first category consists of structural motivations and obstacles. One structural example is the influence of interest groups on leaders' perceptions and behavior, for example the influence of business and corporate interests on legislators. In a climate context, industrial lobbies are powerful interest groups that might inhibit or advance more robust policymaking. Another structural example concerns the tradeoffs that leaders are bound to consider in their official capacities: near-term versus long-term policy questions; fiscal and revenue considerations and constraints (e.g., taxation); prioritization of mitigation versus adaptation policies or investments. Structural considerations intersect via the win-loss calculus that leaders go through when making policy decisions. Carbon taxation, for instance, will negatively impact some groups while benefiting others.

The second category consists of the multiple personal factors that spur or inhibit action. A leader's values, religious beliefs, hopes and fears, ideological convictions, and more all shape each individual's outlook and willingness to act.

Is there a way for VR experiences to cut across this diversity? The answer is yes, at least to a point. VR experiences can be effective if they provoke emotions that remind leaders about their ethically bound responsibilities to themselves, their families, their communities, future generations, and even other species. VR experiences should send a strong reminder to leaders that they are responsible for building a future that is valuable not only for their country or the people they represent, but for their own children and grandchildren. These messages should be included in VR experiences to counteract the human tendency to discount the future, wherein current crises receive most attention while decisions on longer-term challenges such as climate change are pushed into the future.[41]

There is an important caveat here, in that effective communication around climate change, whether that communication occurs within a VR experience or outside it, is a tricky business. The VR developer must consider the insights from climate communications research, which points toward the risk that, absent proper

[41] Climate change is complex, nonlinear, presents radical uncertainty, cuts across temporal and geographic boundaries, and appears distant in space and time. See Art Markman, "Why people aren't motivated to address climate change," Harvard Business Review, October 11, 2018, https://hbr.org/2018/10/why-people-arent-motivated-to-address-climate-change.

packaging, strong climate messages will be viewed as green propaganda, especially by people who are disinclined toward believing in anthropogenic climate change in the first place. As the Pew Research Center concluded in 2016 when examining its survey data on climate change, right- and left-leaning respondents in the United States have "vastly divergent perceptions of modern scientific consensus, differing levels of trust in the information they get from professional researchers, and different views as to whether it is the quest for knowledge or the quest for professional advancement that drives climate scientists in their work."[42] The social media landscape adds another wrinkle, with studies showing that social media has acted as an echo chamber for people who are ideologically inclined to one outcome or another, thereby increasing polarization between those who support action on climate change and those who do not.[43]

C. PUTTING IT ALL TOGETHER: VR FOR CLIMATE LEADERSHIP

Developers need to pay attention to several core issues if their VR experiences are to be impactful in shifting how leaders perceive and act upon climate change.[44]

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[42] "The politics of climate," Pew Research Center, October 4, 2016, https://www.pewresearch.org/science/2016/10/04/the-politics-of-climate/.

[43] Isobel Gladston and Trevelyan Wing, "Social media and public polarization over climate change in the United States," Climate Institute, August 27, 2019, https://climate.org/social-media-and-public-polarization-over-climate-change-in-the-united-states/.

[44] Unless otherwise indicated, insights in this sub-section resulted from dialogue within the Atlantic Council's VR expert advisory committee.

Photo by Tyler Casey on Unsplash.

Photo by Milos Prelevic on Unsplash.

First, VR can have positive impacts on leaders' views and behavior through multiple pathways. For example, VR can be employed as an aperture-expanding tool, to raise awareness of climate-related problems through deeply immersive and often extraordinarily beautiful (or terrifying, depending on design) experiences. A central goal of VR experiences such as *IMMERSE* is to convey the staggering beauty of the ocean to audiences who have never seen Palau's coral reefs in person. From there, it is easy to convey the risks of inaction (in *IMMERSE's* case, to also show the effects of climate on coral bleaching).

VR provides other viable pathways for influencing how leaders perceive climate. One is reframing, the goal of which is to cast climate change through lenses that depart from conventional wisdom. Recasting climate change as an economic opportunity or even a national security challenge in addition to an environmental problem are good examples. VR can vividly portray how climate change will erode a state's national security or generate prosperity through the low-carbon transition, for example by shifting to a world with more (rather than less) technical innovation. Reframing the climate issue helps with agenda setting, which in turn is one step short of policymaking. VR experiences that help shift climate framing can impact leaders' thinking on whether to oppose or support climate-related legislation or where to invest scarce public funds, for instance toward industrial policies that embrace rather than reject the emerging green and blue economy.

Photo by Javier Miranda on Unsplash.

A second core issue for developers is to be sensitive to SDT principles. VR experiences that maximize players' in-game autonomy, competence, and relatedness should be most impactful. The first two desires (autonomy and competence) speak to an individual's agency within the VR experience, the third to their social credentials. Rebecca Koomen, a social psychologist, argues that people "actively manage [their] reputations and maintain belonging to the cultural groups that shape [their] identities," a characteristic of human psychology that can be leveraged to induce greener behavior.[45] VR experiences should be designed to show leaders that their climate-related actions might increase their standing among people they want to impress, including their peers, constituents, and valued others such as family members. Leaders' self-perceptions are rooted in how their reputations will be affected *among these groups*.[46]

A third core issue for developers is to orient VR experiences toward active learning rather than just delivering information about climate change, given that VR is a technology built around interactivity. Players should be placed in VR experiences where they address, if not outright solve, urgent and practical climate-related problems. Extending the arguments embedded in SDT, VR experiences should make players feel like they have the power to do something about climate change based on the impacts of their actions.

A fourth core issue for VR developers is finding the appropriate balance between *scale* and *motivation*. Scale refers to the spatial level within the game. Individual and local or community spatial levels are different from national or international spatial levels. Generally, portraying climate impacts at national and international

[45] Rebecca Koomen, "What's a green nudge?," The Behavouralist, February 20, 2020, https://thebehaviouralist.com/whats-a-green-nudge/.

[46] Ben Worthy and Mark Bennister, "How can we measure political leadership?," OUPblog, June 18, 2017, https://blog.oup.com/2017/06/measure-political-leadership/; James M. Hohman, "How politicians determine how they vote," The Hill, January 15, 2022, https://thehill.com/opinion/campaign/589591-how-politicians-determine-how-they-vote/.

Photo by Karl Groendal on Unsplash.

scales is more complex and requires more complicated policy solutions compared with challenges faced by individuals, households, or local communities. Motivation, in contrast, refers to how the VR experience appeals to the players' emotions. Although every developer should seek to build emotional resonance into a VR experience, given VR's power to vividly portray alternative worlds, not every VR experience can be constructed with the same emotional intensity. A development team should consider how the VR experience will give players actionable information about climate-related behavior in the real world while facilitating an emotional experience that makes this behavior feel worthwhile and important. Establishing a strong emotional bond between the player and the VR content is a big reason why experiences such as *Tree* and *IMMERSE* put the player within a highly localized context, even though the messaging really is about global environmental challenges—forest conservation in the former, oceans conservation in the latter.

Photo by Jen Theodore on Unsplash.

Finally, it should be noted that measuring post-VR experience behavioral change is difficult. There are studies that validate the notion that VR experiences impact how people perceive and act in the real world, but direct scientific evidence of change between pre-and post-experience behavior requires experimental research designs that are implausible to replicate for many development teams. A central challenge is how to measure a change in behavior and link this change in behavior to the intervention provided in the VR experience.[47] For this reason, it may be hard to assess the linkages to the creation of climate policies or voting after a leader is taken through the VR experience. Developers can focus on measuring impact through analyzing how players interact with the experience, for example analyzing gameplay data showing where players spend the most of their time and the parts of the game where players pay closest attention.

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[47] There is literature on various pieces of the VR-behavioral linkages. See, e.g., this review of consumer behavior: Danny Taufik, Marvin C. Kunz, and Marleen C. Onwezen, "Changing consumer behavior in virtual reality: A systematic literature review," Computers in Human Behavior 3 (January-July 2021), https://doi.org/10.1016/j.chbr.2021.100093. On VR and environmental behavioral change, see Jessica Hester, "What if virtual reality can make us better citizens?," Bloomberg, October 4, 2016, https://www.bloomberg.com/news/articles/2016-10-04/how-virtual-reality-can-change-behavior. For evidence of how AR, rather than VR, impacts behavior, see "How augmented reality affects people's behavior," Science Daily, May 22, 2019, https://www.sciencedaily.com/releases/2019/05/190522101944.htm.

Photo by jet dela cruz on Unsplash.

VI. RECOMMENDATIONS

The recommendations below follow logically from the arguments contained in this report. These recommendations are intended for any organization that intends to employ VR to shape how leaders at any level, from local to global, understand, perceive, and act upon climate change.

LEVERAGE VR: This report begins from the premise that VR is a powerful tool that can be leveraged for climate action. As this report has endeavored to show, VR's market size is now large enough that the world's biggest technology companies are investing enormous sums of money in it. VR therefore is a mature technology that will only gain in capability in the years to come. What we think of as a mind-expanding, emotionally compelling, and immersive experience now is going to look tame by the technical standards of five or ten years hence.

In short, not only is VR not going to fade away, but it also almost certainly will become a more powerful and capable technology in the future, with an even larger consumer base reaching into the hundreds of millions, possibly billions, of people over the coming decade.

Photo by Luba Minar on Unsplash.

The most basic takeaway from this report is that organizations seeking to shape climate action should recognize that VR is a compelling and useful technology that can be put into service of a climate-friendly agenda. Numerous organizations already are doing so.

Yet as this report also has endeavored to show, there are important development and design considerations that organizations should heed if they want to use VR to maximize impact on world leaders' perceptions and awareness of climate change as well as their policymaking behavior toward it. The remaining recommendations all point toward how organizations and their VR development teams can realize such impacts.

CRAFT A STRATEGY AND FIND RESOURCES: The VR development team needs to first articulate a coherent strategy to guide the entire project from start to finish. The goal should be to build a coherent roadmap that spells out the project's goals, identifies the consumers of the VR experience, identifies a brand, articulates a marketing and communications plan, identifies the metrics that will assess whether the project is or is not a success, maps out the partnerships and alliances required to achieve the project's goals, and calibrates the strategy to available resources (time, money, partnerships, etc.).

The costs required to develop a VR experience can vary dramatically depending on level of effort, quality of finished product, and supporting material. At the bare-bones end, involving a tiny number of developers, a minimal standalone VR experience can be developed for a few tens of thousands of dollars or euros.

Conversely, a high-end VR experience will require many technical and creative people, a significant marketing effort to ensure that the VR experience is put in front of the targeted audiences, critical supporting infrastructure, ancillary content, and technical equipment necessary to take people through maximal VR experiences (e.g., specially built VR rooms at conferences). *Half-Life: Alyx*, one of the most technically sophisticated and beautifully crafted VR games, is estimated to have cost between 29 million and 75 million dollars (U.S.) to create over a four-year timespan. Although *Half-Life: Alyx* is at the far end of the cost spectrum, organizations that want to build, market, and properly support a rich, compelling, high-end VR experience, should expect costs to run in the millions of dollars or euros.

BUILD PARTNERSHIPS: Creating a VR experience that will have far-reaching impact is difficult to realize using an entirely in-house process. The reason is simple: few organizations have the resources and expertise necessary to both create a rich, compelling, and vibrant VR experience that also is effectively marketed and supported in terms of audience reach. For this reason, organizations should be building partnerships with external organizations that can provide the full range of assets necessary to successfully realize their VR goals. The organization will need to build partnerships that can deliver some combination of intellectual property

development (storytelling and scenario development capacity, scientific expertise, etc.), technical design capabilities (i.e., from the gaming industry), financial support (if necessary), marketing and communications prowess, logistical support, and global networking and convening power (ensuring that the VR experience can be placed in front of world leaders).

DESIGN INCLUSIVELY: Per the above recommendation, the VR development process is difficult and requires cross-disciplinary input to maximize the odds that the VR experience will achieve the organization's goals. Ideally, a full team would include game developers, climate and Earth system scientists, psychologists, social scientists, and public policy experts in addition to marketing, communications, and public relations professionals. The representation of these disciplines' needs to also be diverse in gender, ethnicity, etc.

IDENTIFY THE TARGET AUDIENCE: Consumers of VR experiences are not homogeneous, and no single VR experience can be calibrated for equal impact across all consumer groups. VR developers will have to choose between breadth of VR experience to reach more consumers across more places (countries, regions, etc.) and specificity of VR experience that might reach fewer people but also speak with more precision to specific contexts, conditions, and places. VR experiences for broad application have enormous value, if they are focused on raising awareness and building empathy.[49] Narrower VR experiences will require a more granular understanding of the target consumer group.

[49] A "green nudge" is a positive in-game cue that motivates the player toward environmentally beneficial behavior. See United Nations Environment Programme, GRID Arendal and Behavioural Insights Team, The Little Book of Green Nudges: 40 Nudges to Spark Sustainable Behaviour on Campus, UNEP and GRID-Arendal (2020), https://www.unep.org/resourcespublication/little-book-green-nudges.
Trista Patterson and Sam Barratt, Playing for the Planet – How video games can deliver for people and the environment, UNEP and GRID-Arendal (2019), p. 22, https://gridarendal-website-lives3.amazonaws.com/production/documents/:s_document/506/original/gamingpub2019.pdf?1569241220.

Photo by Lucrezia Carnelos on Unsplash.

For the general public, there are well established research methods for assessing perspectives and motivations, including public opinion and market research polling, focus groups and other direct queries. For leaders, however, such methods are at best sporadic. More frequently, there is little if no direct method to measure leaders' motives, perspectives, and opinions. At some leadership levels, e.g., heads of state, ministers, and national legislators, it will be nearly impossible to conduct first-person market research. Developers will have to substitute other sources of information to impute perspectives and motivations.

For climate-focused VR experiences, the development team also will have to consider how the experience will be received by leaders who have varying levels of commitment to climate action, for example climate skeptics versus climate advocates.[50] Although climate advocates do not need convincing, they will have ties to more skeptical or reluctant peers. A development team might be successful in enlisting them to help recruit peers to go through the VR experience, reinforce important takeaways from the experience, and might help create, through their public platforms and media reach, a 'buzz' around the VR experience.

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[50] Public opinion surveys generally show widespread belief in anthropogenic climate change, with the number of people trusting in the science outweighing skeptics in most countries. Surveys suggest that climate skepticism is higher in the United States, Russia, Japan, Israel, and several Gulf Cooperation Council states than elsewhere, although individual survey results vary. See Moira Fagan and Christine Huang, "A look at how people around the world view climate change," Pew Research Center, April 18, 2019, https://www.pewresearch.org/fact-tank/2019/04/18/a-look-at-how-people-around-the-world-view-climate-change/; Kate Whiting, "3 charts that show how attitudes to climate science vary around the world," World Economic Forum, January 22, 2020, https://www.weforum.org/agenda/2020/01/climate-science-global-warming-most-sceptics-country/; Oliver Milman and Fiona Harvey, "US is hotbed of climate change denial, major global survey finds," The Guardian, May 8, 2019, https://www.theguardian.com/environment/2019/may/07/us-hotbed-climate-change-denial-international-poll.

Photo by CHUTTERSNAP on Unsplash.

DO NOT WASTE TIME: Leaders have limited time and bandwidth for engagement, which in turn means they have limited patience—not to mention willingness—to go through a VR experience in the first place. As developers in many cases will have only one chance to put a VR experience in front of leaders, it is imperative to make that one count. The VR experience will need to be short, at or below ten minutes in length for a complete session.[51]

Developers have a hard task. In a single VR experience, they will need to: (a) enable the player to swiftly and easily understand the VR experience and navigate within it; (b) create a powerful storyline or narrative that gives meaning to the experience; (c) provide a "wow"-factor sensory experience; (d) limit cognitive load, meaning constrain requirements for cognitive processing of data, facts, and other information. These priorities can be field tested in the prototyping stage.

MAKE IT COUNT: Leaders are human beings like anyone else, hence are affected by similar stimuli that appeal to common human emotions. Developers should ensure that the VR experience also connects to leaders' values, hopes, and aspirations, which in turn means ensuring that the experience is stunning to the senses and as emotionally compelling as possible.

However, to maximize impact, developers also must create VR experiences that link climate messaging to leaders' core motivations, as discussed in section V of this report. All other things considered, a VR experience that fails to address how leaders understand their place in the world, no matter how visually stunning or emotionally appealing, will not have as great an impact as one that speaks to leaders' roles as leaders. VR experiences must speak to this consideration in one form or another, which means that developers need to attach leaders' desire to act—to bolster their roles as inspirational leaders—to the climate messaging in the VR experience.

[51] One can envision creating a modular series of linked climate-centric VR experiences, with the format, visual cues, and logic of each module linking logically to the previous and succeeding modules. Leaders could be led through five or six ten-minute VR experiences over a period of days, weeks, or months. But even under this scenario, the first VR experience nonetheless remains key. It will be impossible to recruit leaders to participate in a full modular series if the first version does not produce a compelling experience sufficient to overcome the above obstacles to participation.

Photo by Vincent Camacho on Unsplash.

Developers should incorporate SDT principles through maximizing leaders' senses of autonomy, competence, and relatedness. Leaders perceive their roles through the two big categories outlined in section V (structural and personal factors motivating their actions). In the VR experience, developers might have the leader, in their role as someone with the power to alter the future, make decisions about climate change, and then subsequently experience the consequences from the point of view of a constituent. Placing leaders in the viewpoint of their constituents by giving them an avatar within the game may be effective at building empathy with others.[52]

DEFINE THE DELIVERY METHOD: How does an organization intend to get its VR experience in front of leaders? There are two basic pathways. The first is a standalone experience with minimal device input, e.g., just an HMD plus handheld devices. Standalone VR experiences are less expensive, run at lower graphical fidelity, require no specific room, forum, or venue, and are highly portable. The development team would need to develop a strategy for getting the experience in front of leaders, for example having individual leaders go through the VR experience on a headset in their office.

The second is a much more intensive experience involving more devices and sensory inputs, are more expensive, utilize higher-end hardware with higher graphical fidelity, and (often) will require purpose-built VR rooms to be installed at leadership forums. This option necessitates greater expense, development, planning, opportunity, and execution and requires that the organization has the network and power to get the experience formally placed at leadership conferences.[53]

[52] Proulx, Romero, and Arnab 2016.

[53] There are hybrid solutions. The developers of the In My Shoes VR experience developed a web-oriented marketing strategy to draw the public to their website while finding ways to bring the experience to audiences at tech conferences, museums, universities, and communities. See https://www.inmyshoes.us/. There also are multiplayer VR options, which are more complex and expensive and would require getting multiple leaders into the same experience simultaneously.

Regardless of the delivery method, any organization that wants to have world leaders go through its VR experience should not underestimate the access challenge in front of them. The organization will need a competent and well-connected team who can access the key stakeholders within leaders' advisory circles. The team will need to have the connections, skill, savvy, and drive to successfully pitch the VR experience to the leaders' advisors, and subsequently have them schedule the leaders' interaction with the VR experience at a specific time and place. A follow-up plan after the VR experience will be built into the delivery method strategy.

IN-GAME TACTICAL DECISIONS MATTER: When creating climate scenarios for a compelling VR experience, the development team needs to consider and harmonize multiple 'tactical' considerations that shape the player's in-game VR experience and therefore their reactions to it. This report's analyses point in the direction of how to perform this difficult task. The recommendations are as follows:

a

NARRATIVE: What is the narrative about climate change and climate action? Developers need to fixate on more than just topic (e.g., drought or flooding) and view the VR experience as a form of interactive storytelling. The experience cannot be just a random walk through a virtual world, say a coral reef, city, or forest, no matter how visually stunning that world is. Rather, as in the *Tree* example, the player needs to move through a narrative thread that binds the experience from beginning to end.

b

CLIMATE IMPACTS: Each type of climate impact—extreme heat, drought, flooding, sea level rise, storms, etc.—introduces different visual, auditory, vibration, temperature, and other sensory impressions. A maximum VR experience will utilize haptic devices that can simulate these diverse sensory impressions, such as vibration, heat, cold, wind, smell, and so on. Developers, of course, can forego using haptic devices that simulate any or all these impressions. Such decisions will require that the developer balance tradeoffs involving complexity, cost, and fidelity.

c

STRUCTURE: The developer must build a structure that gives the player the means to navigate the game, including waypoints, signals, and other devices to get from start to finish. The goal is to not give the player complete freedom of action, which would lead the player to perceive the experience as pointless and frustrating. Narrative should connect to decisions and therefore outcomes, which in turn create purpose for the player and a meaningful experience.[t] One way to do this is to have the player make choices that affect future worlds (alternative scenarios) of the player's creation, which the player then can experience.

d

SCENARIOS: The scenario method—creation of different (alternative) future worlds based on choices the player makes in the present—is a way for developers to build positive, hopeful, and pro-social content as well as negative and fear-based content into the same VR experience. Although it might be technically feasible to have the player make

[54] Scott Rigby terms such VR experiences "narrative impact" games, wherein players are given a "narrative purpose" and "meaningful choices" from beginning to end. Rigby, "Fallacy," at 26:00 forward.

choices resulting in an almost limitless number of future climate scenarios, the player also must believe that their choices have real future consequences. Hence, the player's decision making in the VR experience must be linked to tangible differences across future scenarios. Scenario number depends on the types of choices that the player makes, the outcomes tied to those choices, and the developers' budget to craft multiple scenarios (a larger number implies greater cost).

TIME PERIOD(S): When will the VR scenarios take place in the future? Next year? Ten years from the present? 2040, 2050, 2060, or beyond? A mix of years? As climate impacts will become more severe in the more distant future, it will be easier to portray more dramatic impacts set further out into the future. However, portraying scenarios over longer time horizons runs into the human predisposition to value the nearer over the longer term. This problem is particularly acute for leaders, especially where electoral time horizons are short. One possible solution would be to have the player make choices in the present that impact multiple future years.

e

SCIENTIFIC CREDIBILITY: To avoid criticism that the VR experience is unrealistic or biased, the development team needs to use the best available science. Yet, science cannot inform a single best year or emissions pathway to portray in future scenarios. The Intergovernmental Panel on Climate

f

[55] V. Masson-Delmotte et al., eds., Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, IPCC (Cambridge University Press, 2021), Box SPM.1 and Table SPM.1, pp. 12-14.

Photo by NASA on Unsplash.

Change's (IPCC) most recent Assessment Report (AR6, 2021) does not forecast notable temperature differences across its five emissions scenarios until the 2040s, and widely divergent differences not until the 2080s.[55] Regardless, the development team must calibrate the scenarios with reliable scientific forecasts about how future climates likely will unfold and over what time periods.

g **GEOGRAPHY:** Should the VR experience portray real, specific places or imagined places? If the former, which places? This question overlaps with the breadth of the targeted leadership group. For VR experiences that are designed for a broad leadership audience, e.g., at global levels, the portrayal of specific places runs the risk that some leaders might find little connection and therefore inspiration. Portraying imagined places brings with it the opposite problem, which is that an imagined place might feel unreal, hence, not to be taken seriously.

h **AVATAR:** Will the leader go through the VR experience as themselves or someone else? The obvious solution is to have a leader go through the entire VR experience as a first-person observer and actor. The leader's decisions can be linked to climate outcomes and from there to considerations close to them—direct and indirect impacts on constituents, for example. Another option is to have the leader go through the experience from the standpoint of a constituent, for example from the point of view of a child or young adult, who is impacted by policies made by their leadership. Non-first-person avatars can help leaders build relatedness and from there to empathy.

10

BRAND AND COMMUNICATE: Finally, a design and development process should not end with the creation of a compelling VR experience. Rather VR experiences are branding and communications opportunities, and therefore should be embedded within robust, long-term, targeted and well-resourced strategic communications efforts. The VR experience itself should be given a strong brand that then is repeated across the organization's digital, print, social, and other media platforms. (Think of the branding that has gone into VR experiences such as IMMERSE or Tree.) The rationale is partly to have the VR effort augment the organization's reputation. But the more important rationale is that a strong brand, buttressed by a strong communications effort, will increase the visibility and therefore impact of the VR experience among leaders and the general public, which after all is the point of the exercise.

Photo by NOAA on Unsplash.

VII. CONCLUSION

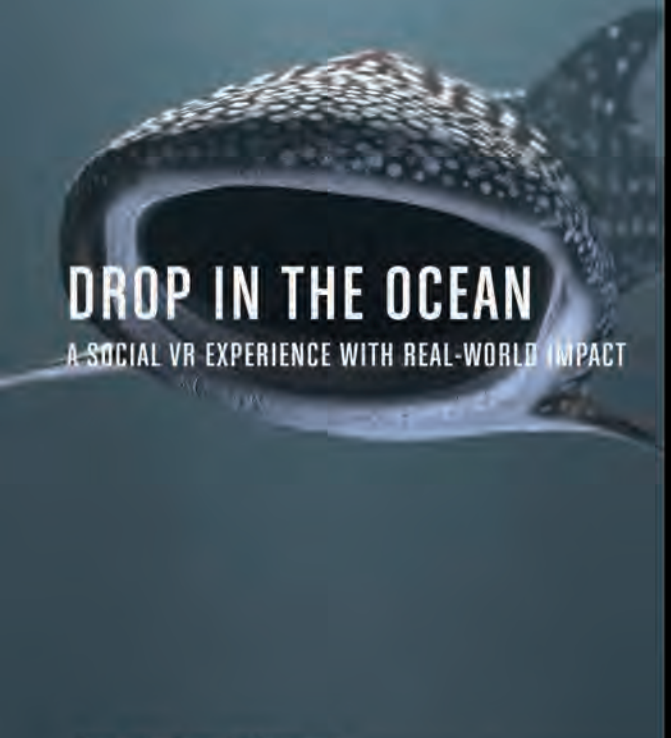
VR is not a panacea for solving the world's climate problems. However, VR is an exciting technology that can provide global audiences with intense, motivating, fulfilling, and resonant visceral experiences. As such, VR offers enormous promise for organizations that want to employ it in service of pro-climate agendas. VR should be seen as a capable and innovative tool, a sleek piece of technology that can shift how humans, including leaders, perceive climate change. Moreover, as described in sections V and VI of this report, if properly positioned and marketed, VR experiences can be leveraged for significant impact around climate messaging.

Leading organizations therefore should embrace VR as a means for engaging global leaders. This claim means that VR provides the starting point, rather than the endpoint, of a systematic, structured, and ongoing engagement with world leaders. As summarized in section II of this report, the Atlantic Council intends to treat VR in just these terms. The Atlantic Council will accelerate its reach and positioning in this space, with the goal being to have its VR experiences become an effective means for sustained and actionable dialogue with the world's leaders on the growing challenges and opportunities presented by a changing climate.

Photo by JOHANNA MONTOYA on Unsplash.

> ***What excites you most about VR?***
>
> ***It's a medium that puts you in a really interesting mindset. I describe it a bit like ultra lucidity, a way of looking at things similar to when you are traveling, or in a context where you're looking with bigger eyes.***
>
> ***— Vincent Morriset, director and founder, AATOAA***

Photo by Antonio Garcia on Unsplash.



Drop in the Ocean VR Experience
https://www.conservation.org/stories/virtual-reality/drop-in-the-ocean

APPENDIX 1: VR EXPERIENCES FOR ENVIRONMENTAL IMPACT

Environmentally focused VR experiences can be grouped into several categories, as summarized here.

The first category relies heavily on fear-based messaging. These VR experiences motivate players through immersing them in worlds going through the catastrophic effects of climate change. For example, the VR studio Condition One released a four-part 360-degree VR film series, *This is Climate Change*, showing the impacts of climate change. Titled *Fire, Famine, Feast*, and *Melting Ice*, the films stress the spread of wildfires, drought and famine, deforestation, and melting glaciers respectively.[56] The Weather Channel produced a widely viewed immersive mixed reality experience detailing the dangers of flash flooding, emphasizing the growing risks of flash flooding due to climate change, and educating viewers about how to protect themselves in the event of flash floods.[57]

A second category of VR experiences still emphasizes environmental threats but dials back fear-based messaging. Penn State scientists are creating a forest in VR that allows users to experience various climate outcomes.[58] The *Drop in the Ocean* immersive VR experience, which debuted at the 2019 Tribeca

[56] Danfung Dennis and Eric Strauss, "This is Climate Change," MIT, 2018, https://docubase.mit.edu/project/this-is-climate-change/; D. Hardawar, "In 'This is Climate Change,' you can't look away from the destruction," Engadget, April 22, 2018, https://www.engadget.com/2018-04-22-this-is-climate-change-vr.html.

[57] The Weather Channel, "The Dangers of Flash Floding," October 24, 2019, https://youtu.be/PvJuocemHS4.

[58] Sarah Brodsky, "How VR Could Show the Future of Climate Change," Lifewire, June 21, 2021, https://www.lifewire.com/how-vr-could-show-the-future-of-climate-change-5189623.

[59] Adam May, Chris Campkin, Chris Parks, "Drop in the Ocean, MIT, 2019 https://docubase.mit.edu/project/drop-in-the-ocean/.

film festival, allows users to spend seven minutes exploring the impact of plastic on the oceans. Users feel as though they are shrunk to two inches tall and riding on the back of a jellyfish. The game uses body tracking so that participants can see their own bodies and those of other users within the VR headset.[59] *Climate Crimes* is an immersive experience that explores the interconnectedness of climate change issues, projecting videos on a dome in which visitors are invited to lie down and observe. The videos use atmospheric data gathered by satellites to explore the causes and effects of pollution.[60] Stanford's VR lab has released *The Crystal Reef*, a project which shows players a 360-degree video of Italy's coastal reefs while a marine scientist explains their ongoing destruction due to GHGs.[61] The *Greenland Melting* 360-video experience from Emblematic allows viewers to experience the full significance of melting arctic ice via a VR HMD.[62] Similarly, The Hydrous developed *IMMERSE*, a 360-degree film, to help viewers understand the threats faced by coral reefs due to climate change. The *IMMERSE* experience can be utilized via VR, AR, or by viewing an immersive video.[63] Finally, Virtual Planet works with many partners to release VR experiences, mixed reality experiences, and 360 degree videos and apps allowing players to interact with and experience the real-world effects of climate change.[64]

Gamification is another approach in VR. Students at a Yale University annual event called "The Reality of Global Climate Change: A Mixed-Reality Hackathon" have created VR games based around carbon emissions, wherein players combat carbon dioxide emissions and absorb graphs reflecting policy decisions.[65] Glimpse Group is in the process of developing an online VR game based on a book by Vanessa Keith (titled *2100: A Dystopian Utopia / The City After Climate Change*), which will have players explore, manipulate, and try to protect future climate-altered cities.[66]

[60] Adrian Lahoud and Michaela French, "Climate Crimes," MIT, 2018, https://docubase.mit.edu/project/climate-crimes/.

[61] Virtual Human Interaction Lab, "The Crystal Reef," Stanford University, https://www.stanfordvr.com/the-crystal-reef/.

[62] Sol Rogers, "Could Virtual Reality Make Us Care More About Climate Change?," Forbes, November 1, 2019, https://www.forbes.com/sites/solrogers/2019/11/01/could-virtual-reality-make-us-care-more-about-climate-change/?sh=3f06658d1340.

[63] Ibid; The Hydrous homepage is at https://thehydro.us/.

[64] "About," Virtual Planet, https://virtualplanet.tech/.

NASA Earth Observatory images by Joshua Stevens, using Suomi NPP VIIRS data from Miguel Román, NASA's GoAddard Space Flight Center

Some VR experiences focus on user autonomy and choice for climate action. The United Nations Environmental Programme (UNEP), in collaboration with Sony PlayStation, created an immersive VR experience that allows users to learn about their carbon footprint and see the tangible impact of their everyday actions. Throughout the experience, users are guided by a massive ball of gas—representing their carbon footprint—and ultimately see their impact transform into sea-level rise.[67] *Future Earths* takes a slightly different approach to engage users directly with environmental solutions. It provides several opportunities for users to engage with climate-related topics, including a short VR game that allows users to explore an underwater habitat, turning off machines to clean the water, and an experience in which participants share stories about working together to overcome climate change.[68] Finally, Eco Resilience Games creates a variety of different media projects and interactive games intended to drive environmental action among young people. Their products to date include *The Aquatic Messenger*, a VR game about plankton designed for middle and high school students; *Algae Bloom Dynamics*, an AR game about fixing toxic algae blooms; and *Trophic 3D*, a VR game that illustrates a freshwater food web.[69]

[65] Rogers, "Could Virtual Reality Make Us Care More About Climate Change?"

[65] Kristen French, "Can Virtual Reality Save the Planet," State of the Planet, August 18, 2021. https://news.climate.columbia.edu/2021/08/18/can-virtual-reality-save-the-planet/.

[66] "Experience your Carbon Footprint in VR," UNEP, June 25, 2020, https://www.unep.org/news-and-stories/story/experience-your-carbon-footprint-vr.

[67] "Climate Change VR," Graviton, https://meetgraviton.com/flv_portfolio/climate-change-vr/; "Future Earths: Climate Change Simulator," Graviton, https://meetgraviton.com/flv_portfolio/climate-change-simulator/.

Can ancient forms of plankton from over 10,000 years ago help us understand the future of freshwater ecology?
The Aquatic Messenger
https://store.steampowered.com/app/1955040/The_Aquatic_Messenger

Can ancient forms of plankton from over 10,000 years ago help us understand the future of freshwater ecology?
The Aquatic Messenger
https://store.steampowered.com/app/1955040/The_Aquatic_Messenger

Other products expose viewers to biomes outside of their everyday experience to motivate conservation efforts. *Only Expansion* is an immersive real-time audio experience in which participants can walk through a physical site with nature sounds overlaid, depending on the route that participants choose.[70] *BRINK Traveler* provides VR and AR applications that allow players to virtually visit different locations, take pictures, and read information about the locations through 360 video technology. Although the players' movement in the spaces is limited, the experience is still realistic and immersive.[71] Many of the locations are natural wonders that will be impacted by climate change in the future. *We Live in an Ocean of Air* is a 20-minute VR experience intended to help viewers understand the connections that humans share with the natural world, including by sharing breath and heart sensor data to track users' breathing.[72] Some existing VR systems have the capacity to have this same effect, although they are not intended to

[68] "Eco Resilience Games," Global Games Research Group, https://sites.google.com/view/eco-resilience/home.

[70] Duncan Speakman, "Only Expansion," MIT, 2019, https://docubase.mit.edu/project/only-expansion/.

[71] "About," Brink XR, https://www.brinkxr.com/.

[72] Rogers, "Could Virtual Reality Make Us Care More About Climate Change?"

stimulate climate action. Google Earth VR has much of the world already mapped out with 3D modeling that a user can explore. However, despite its impressive and immersive design, it does not include climate change-related content.[73]

Documentary-style experiences within this genre introduce participants to the human victims of climate change. *The Last Generation* is an interactive web documentary focusing on the stories of three children in the Marshall Islands and their futures under the threat of climate change. Viewers can move between scenes and experiences within the documentary.[74] *The Great Green Wall* project released a documentary-style VR video in 2016 on the effects of climate change on one rural community in Senegal and efforts to regrow plants in the area, planting acacia trees that restore the groundwater.[75] The video is narrated by a young girl from the community. Finally, Conservation International's *Under the Canopy* is a 360 video shot with an indigenous community in the Amazon that allows viewers to explore the region and emphasizes the need for expanded conservation efforts.[76]

Other similar experiences focus on the animal and vegetal victims of climate change. Tree is a full-sensory VR experience that transforms users into trees in the rainforest, with their arms as branches and their torso as the tree trunk, allowing them to experience the full life span of a tree. Haptic feedback and on-site smells immerse participants in their role.[77] Removing the participant slightly from the narrative, *Beyond the Diorama* is an immersive climate change experience created by the Natural History Museum of Los Angeles County, in conjunction with a group of USC students. The experience follows a group of caribou impacted by climate change.[78]

Finally, several VR experiences have already been introduced to world leaders. The creators of the *Stanford Ocean Acidification Experience*, a VR experience showing the

[73] Google Earth VR, Google, https://arvr.google.com/earth/.

[74] Katie Worth and Michelle Mizner, "The Last Generation," MIT, 2018, https://docubase.mit.edu/project/the-last-generation/.

[75] "Growing a World Wonder," Great Green Wall, December 9, 2019, https://youtu.be/pc3BTMVPIwc.

[76] "Under the Canopy," Conservation International, February 15, 2017, https://youtu.be/5JvJCvdqvYs.

[77] Milica Zec and Winslow Porter, "Tree," MIT, 2017, https://docubase.mit.edu/project/tree/.

[78] "About," Beyond the Diorama, https://beyondthediorama.com/.

impacts of ocean acidification, presented their work to US senators.[79] At a higher level, Biosphere VR has released a number of stereoscopic videos, viewable in VR, that show important sites around the world most impacted by climate change. Viewers are guided through the scenes by individuals experiencing these impacts, including Ethiopian farmers who have lost their crops due to drought and a Beijing doctor battling lung cancer. Biosphere VR exhibited five of its experiences at the recent COP 26 meeting, in conjunction with Action Aid, UNESCO and Climate Change Film Festival.[80]

[79]Virtual Human Interaction Lab, "The Stanford Ocean Acidification Experience," Stanford University, https://www.stanfordvr.com/soae/.

[80]"About," Biosphere VR, https://www.biospherevr.com/.

Photo by stephan sorkin on Unsplash.

APPENDIX 2: VR TECHNOLOGIES

PRIMARY VR DEVICES

Currently, almost all VR products contain three primary devices. These are a Head-Mounted Display (HMD) plus two motion controllers (one for each hand). The HMD has either two small display panels (one for each eye) or a single panel running across the player's field of vision. The devices with two panels typically allow users to adjust distance between the screens to match their interpupillary distance, providing a clear picture. Regardless of panel type, the HMD display sends slightly different images to each eye to create an immersive, three-dimensional view of an image, video, or simulated scene. Motion controllers are made specifically for left and right hands (many VR applications and games require the use of both hands). They generally have a pressure-sensitive button for the player's grip with the middle finger and a trigger for the index finger. The controllers typically have some combination of the following: a joystick; a touch-sensitive surface; and buttons controlled by the thumb.

STANDALONE AND TETHERED DEVICES

An important distinction between VR devices centers on whether the device is standalone or tethered. Standalone HMDs have a built-in computer with its own graphics processor, which can display video, images, and even games. To deal with cost and the weight of the headset, standalone hardware is generally a bit more powerful than what's in a smartphone, but less so than the hardware in a high-end gaming computer with a strong graphics card. By comparison, tethered VR HMDs plug into a laptop or desktop computer, which allow the device to

Photo by Laurens Derks on Unsplash.

forgo its own onboard processors, instead having the computer send the video and audio to the HMD via the cable. For users who have a powerful computer, tethered devices allow them to experience greater graphical fidelity. The image can be refreshed faster to create smoother motion, better lighting and more detailed 3D models can be displayed. In sum, tethered headsets provide a better VR experience but are more expensive and cumbersome to use (they are not as portable as standalone devices).[81]

TRACKING

Another important distinction among VR devices is their method of tracking the HMD and motion controllers. Tracking refers to the process of taking a player's physical movements and digitizing them, allowing the player to explore, interact, and experience the virtual world.[82]

Tracking occurs via one of two methods, inside-out tracking, or outside-in, both of which refer to where the sensors are in relation to the HMD.[83] Early VR systems

[81] Raul Mercado, "Which is best for VR: mobile vs. tethered headsets," makeuseof.com, August 9, 2021, https://www.makeuseof.com/which-is-best-vr-mobile-vs-tethered-headsets/.

[82] "A Brief Guide to VR Motion Tracking Technology," ST Engineering Antycip, July 10, 2019, https://steantycip.com/blog/vr-motion-tracking/.

used outside-in tracking, which works by placing sensors around the room. The sensors then determine where the HMD, motion controllers, and additional motion trackers are, then orient the devices to the play space. Inside-out tracking uses cameras inside the HMD to locate itself and motion controllers in the play space. A camera located within the HMD determines how its position is changing relative to the external environment, which the system then recalibrates to match virtual movement with real.[84] Inside-out tracking is ideal for standalone VR systems and has become accurate enough for almost all applications and games.[85]

"Full-body tracking" refers to how a VR system tracks the player's full body movements (legs, arms, etc.), which are then replicated in the virtual setting. A popular current full body tracking system is the VIVE Tracker 3.0, which works by having the user wear several trackers over their body. These trackers use outside-in technology to track a player's full body movements, allowing for a more immersive experience.[86] For future VR devices, manufacturers are trying to achieve full-body tracking with inside-out cameras for a solution that is cheaper and more flexible.

Photo by Arteum.ro on Unsplash.

Eye tracking is a feature that tracks where the user's pupil is focused on the display inside the VR headset. Eye tracking works by measuring the distance between the pupil's center and the reflection of the cornea, allowing the computer system to detect where the gaze of the eye is directed.[87] Eye tracking enables features like foveated rendering (where only the image that the user is looking at is rendered) to provide better image detail, having avatars match the user's gaze for improved social interactions, and navigating menus hands-free. Eye tracking is currently mostly available on business-focused headsets but is expected to come to many consumer headsets soon.[88]

[83] Hugh Langley, "Inside-out v Outside-in: How VR tracking works, and how it's going to change," Wareable, May 3, 2017, https://www.wareable.com/vr/inside-out-vs-outside-in-vr-tracking-343.

[84] Ibid.

[85] Ibid.

[86] Pavel Nuzhdin, "VR full body tracking: do you really need it?," Exyte, March 30, 2020, https://exyte.com/blog/vr-full-body-tracking/.

[87] Bryn Farnsworth, "What is VR Eye Tracking, IMotions, February 11, 2020, https://imotions.com/blog/vr-eye-tracking/.

[88] Scott Stein, "Watching Me, Watching You: How Eye Tracking Is Coming to VR and Beyond," CNET, February 21, 2022, https://www.cnet.com/tech/computing/watching-me-watching-you-how-eye-tracking-is-coming-to-vr-and-beyond/.

IMAGING

Given the wide variety of devices available, VR image content takes different forms, utilizing combinations of video, images, and simulations like games and business applications. Video, including 3D video, and images can be rendered with a simulation or recorded in the real world. Specialty cameras can record 3D scenes from multiple positions at once.

A popular option for VR video content is stereoscopic video, which uses two videos in the same frame, oriented one on top of the other, or side-by-side. Both videos then are projected on a sphere to give the player a wide view, typically 180 or 360 degrees of vision.[89]

While stereoscopic video is the most popular 3D video method, Google has pioneered a method called Light Field Video, which records from 46 cameras at once and generates 3D objects for a format that can be viewed on a variety of platforms. While stereoscopic video is locked into the location where the camera took the video, only allowing the user to turn their view, light fields allow the player to move off a center point, in turn providing an immense sense of depth. This method gives an extraordinary level of realism and immersion in VR.[90]

[89] Emma Rose, "What Makes VR Look Real? A History of Stereoscopic Technology," Idea Rocket, October 13, 2021, https://idearocketanimation.com/23221-what-makes-vr-look-real/.

[90] Devin Coldewey, "Google's 46-camera 'light field videos' let you change perspective and peek around corners." TechCrunch, June 23, 2020, https://techcrunch.com/2020/06/23/googles-46-camera-light-field-videos-let-you-change-perspective-and-peek-around-corners/.

Photo by Colin Lloyd on Unsplash.

None of the video options, however, enable the user to interact with or change their surroundings, which is only possible with real-time simulations built on video game engines. Gaming software simulates a 3D space and creates two images, one for the left and right eyes, many times per second. This requires a highly capable standalone device or a tethered device attached to a powerful computer that can run the simulation and its graphics processing. Gaming simulations allow the player to provide inputs, especially with motion controllers, to change the simulation itself and see the result in real-time.

LOCOMOTION, SCENT, TASTE

While many VR experiences use an HMD (standalone or tethered) and two motion controllers, other devices are available. There are many options for creating a more immersive experience, including sensory implements, motion trackers, suits that provide haptic feedback, and omni-directional treadmills.

Current VR devices manage visual and audible feedback, and many controllers offer some haptic (touch) feedback, albeit in a limited capacity. Scent and taste have proven much harder to replicate in VR. Vaqso has a VR device that can provide five different scents in a VR experience. Vaqso works by attaching a kit to the bottom of a VR headset, which then emits scents that are pushed towards the player's nose by a small fan. Vaqso can connect to any HMD and contains a variety of scents including "fish," "grassland," and "ramen."[91]

For touch, companies like Subpac, Woojer, and bHaptics offer haptic suits and gloves that use audio transducers or motors to provide vibration and pressure to the player's body, making sounds, touching, and impacts feel far more

[91] "About," VAQSO, https://vaqso.com/#Specification.

immersive than audio and video alone. VR startup HaptX's product works by having the user wear specially constructed gloves that are fitted with air pockets. These pockets are compressed and decompressed in real time, displacing the user's skin the way a real object would, allowing the user to experience the simulation of touch. These products also work to apply resistive force to the user, allowing them to feel like they are grabbing a real object.[92]

Locomotion, referring to replication of walking and running, is technically difficult. Locomotion in VR can take several forms. Redirected walking allows the player to move freely through a cleared space (i.e., a room), which in turn is constrained by the room's sensor boundaries. Omnidirectional treadmills conform to the player's direction of travel, providing the feeling of

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[92] Janko Roettgers, "How 'Ready Player One' Compares to Today's VR Technology," Variety, March 29, 2018, https://variety.com/2018/digital/news/ready-player-one-vr-tech-1202739419/.

unconstrained movement.[93] Infinadeck uses a treadmill design that follows the player in any direction, while other devices like Cyberith's Virtualizer ELITE 2 enable players' feet to slide on the walking surface to keep them in place as they walk.

PHASING-OUT OF MOBILE PHONE VR

Some early VR devices were powered by mobile phones. These devices were essentially eyeglass-like frames that slotted a smartphone behind lenses to be used as the display. The smartphone then became the processor to run VR programs. One such product was Google Cardboard, released in 2014.This made VR accessible to many people with a modern Android smartphone, as they could get a device anywhere from around ten dollars (US) for Google Cardboard or closer to eighty dollars (US) for Google's more premium Daydream headset.[94] By 2020, VR support for Google Cardboard, and its main competitor in mobile VR, Samsung Gear, had been discontinued. Google stopped working on these devices and software as they did not attract the expected customer base.

CURRENT AND FUTURE VR SYSTEMS

This section provides a brief overview of current VR systems and systems that are anticipated to be developed in the future. This is not an exhaustive overview, rather a sampling of the largest and most established devices and companies on the market.

The current Windows Mixed Reality System uses the HP Reverb G2 HMD. While designed for the Windows Mixed Reality platform, the HMD itself has no mixed reality capabilities and is a purely VR system. It is designed and advertised primarily for business, productivity, and educational applications, but can be used for gaming. There is also an edition with sensors that can monitor one's pulse, movement, eye gaze, and pupil size.[95] Valve's Index HMD is tethered to a

[93] Ivy Wigmore, "VR Locomotion," TechTarget, https://www.techtarget.com/whatis/definition/VR-locomotion-virtual-reality-locomotion.

[94] Ron Amadeo, "Googles VR dreams are dead: Google Cardboard is no longer for sale," ArsTechnica, March 3, 2021, https://arstechnica.com/gadgets/2021/03/googles-vr-dreams-are-dead-google-cardboard-is-no-longer-for-sale/.

Photo by Matthew Kwong on Unsplash.

gaming PC or laptop and uses outside-in tracking with at least two SteamVR 2.0 sensors. The Valve Index displays have a high refresh rate of up to 144 Hz compared to the 80-90 Hz of most displays, meaning the image on the display is updated more times per second, making motion look more realistic[96] Meta's Quest 2 was the best-selling VR set of 2021.It does not require tethering to any other devices, and it has built-in cameras for inside-out tracking.[97]

Most known details that have been publicly released about upcoming headsets point to further refinement of the current VR features, and further reducing costs for consumers. Valve appears to be working on a new headset called "Deckard" that's very likely to have improved optics, and possibly inside-out tracking with a standalone mode.[98] Meta's next standalone HMD, currently called Project Cambria, is a mixed reality headset using more advanced cameras.[99]

Apple is expected to be close to an announcement of a standalone HMD that is capable of both mixed and virtual reality utilizing the Reality OS they're building specifically for the device. Other details are sparse, but an early version of the headset was shown to its board of directors in May of 2022.

[95] "HP Reverb G2," HP, https://www.hp.com/us-en/vr/reverb-g2-vr-headset.html.

[96] "Valve Index VR Kit," Steam, https://store.steampowered.com/sub/354231/.

[97] Isaiah Richard, "Meta's Oculus Quest 2 is the Top Selling VR Headset of 2021," Tech Times, March 21, 2022, https://www.techtimes.com/articles/273303/20220321/meta-s-oculus-quest-2-top-selling-vr-headset-2021.htm.

[98] Sam Machkovech, "A new 'standalone' Valve VR headset teased by deep SteamVR file drive," Ars Technica, September 28, 2021, https://arstechnica.com/gaming/2021/09/a-new-standalone-valve-vr-headset-teased-by-deep-steamvr-file-dive/.

[99] Scott Stein, "Mark Zuckerberg Just Showed How Meta's Next Mixed Reality VR Headset Will Work," CNET, May 12, 2017, https://www.cnet.com/tech/computing/mark-zuckerberg-just-showed-how-metas-next-mixed-reality-vr-headset-will-work/.

Photo by Jessica Lewis on Unsplash.

[100] Michael E. Porter and James E. Heppelmann, "Why Every Organization Needs an Augmented Reality Strategy," Harvard Business Review, https://hbr.org/2017/11/why-every-organization-needs-an-augmented-reality-strategy.

APPENDIX 3: AUGMENTED REALITY

AR'S POTENTIAL AS A TOOL TO COMBAT CLIMATE CHANGE

Like virtual reality, augmented reality (AR) can be a tool to combat climate change. AR is the use of information in the form of text, graphics, audio, or otherwise that are integrated with real world objects. By overlaying digital elements onto the real images from the players location, relying on geolocation, AR augments how a person views, interacts, and navigates with the real physical world. AR works by allowing users with a camera-equipped device that allows the user to see information superimposed on the 3-D image viewed on their device. AR equipped devices include smartphones, tablets, and even AR glasses. While AR glasses are widely seen as the future of the technology, it is via smartphones that most people access the technology today. There is no need for a specialized headset or the motion controllers required for an individual to utilize the experience such as there is in VR.

There are three key capabilities provided by AR—the visualization of data, instruction and guidance, and interaction.[100] AR can provide powerful, real-time insight into the effects of climate change by bringing scientific data into the hands of ordinary people. For example, complex projections on how climate change will cause sea levels to rise and change coastlines can be inaccessible for some people without consuming scientific text. AR applications can overcome this, bringing scientific information directly to individuals' smartphones, thus allowing users to visualize the impact of climate change in real-time and providing an understanding of the data.

AR can also allow for the instruction of climate-friendly behavior. A user can scan a product to view a visualization of the proper disposal techniques and be guided by AR to take more environmentally friendly actions.

There are numerous games which utilize AR technology for interaction. These applications function similarly to the *Pokémon Go* game in that they overlay animations that the player can interact with on the screen using the smartphone's camera. The ease by which a person can access an AR application and its widespread availability due to the prevalence of smartphones has led to several AR applications being developed with the explicit purpose to combat climate change.

Illustration by Declan Blasini
Photo by Lance Asper on Unsplash.

TECHNOLOGICAL DIFFERENCES BETWEEN VR AND AR

AR technology became distinct from VR in the early 1990s and gained prominence when TV sportscasts started to overlay lines on American Football fields to indicate the first down.[101] Today, consumers can experience AR through several technologies. These include AR-specific devices such as Microsoft's HoloLens or other soon-to-be commercially available "smart glasses" such as Apple's rumored AR device or Snapchat's Spectacles or via the heads-up displays common in newer cars. Wearable AR devices relay digital information to the player in real time as they transit the actual physical environment[102] These devices are costly and have limited functionality. Despite large private sector investment in wearable AR technology, it has not yet reached its potential.

AR experiences can be broken down by marker-based and markerless characteristics. Marker-based AR relies on the image recognition of preprogrammed objects into the AR device or app if using a smartphone. Once the camera detects a marker (for example a QR code) it compares this marker with markers in its programming. Once the correct marker is selected, it displays the AR image in the right place. For example, if you are at a museum, you may scan a QR code next to an artifact. After doing so, the AR image would display additional information, or an immersive experience overlaid on the camera's field of view.[103]

Markerless AR works slightly differently, as there are no pre-programmed markers. The AR device has instead been programmed to recognize items as they come into its field of view. This can be based on patterns, colors, or other features that will indicate something to the AR device. Pokémon Go is an example of a markerless AR experience. It relies on a user's phone and the user's location information to overlay an AR experience.

[101] "Augmented Reality (AR) Vs Virtual Reality (VR)," Splunk, https://www.splunk.com/en_us/data-insider/what-are-augmented-reality-and-virtual-reality.html.

[102] For a summary of AR's divergent definitions, as well as provision of a consensus definition, see Niek Zuidhof, "Defining smart glasses: A rapid review of state-of-the-art perspectives and future challenges from a social sciences' perspective," Augmented Human Research 6, 15 (2021), https://link.springer.com/article/10.1007/s41133-021-00053-3.

[103] "The Science of Augmented Reality," The Franklin Institute, https://www.fi.edu/science-of-augmented-reality.

Photo by Mika Baumeister on Unsplash.

AR operates in contrast to VR, as it only adds to someone's vision, compared to VR which replaces one's vision. This difference is also seen in the technical differences between the two products. VR relies on HMDs which create a completely immersive experience and high-fidelity sound and motion. AR does not use the head-mounted devices or motion controls of VR. Despite these differences, AR and VR should be viewed as should be viewed as complementary rather than oppositional. The boundaries between the two technologies already are blurring such as in Meta's concept of the "metaverse," which will almost certainly will utilize both AR and VR elements, simultaneously or sequentially, to engage its consumers'.[104]

HOW AR CONVEYS CLIMATE MESSAGING

Several existing AR applications convey the impacts of climate change. For example, After Ice is an AR application that allows players to simulate the impacts of sea-level rise.[105] *After Ice* uses NASA projected sea-level rise to allow players to see impacts within a 100-mile radius of New York City in the 2080s. Similarly, a filter developed in 2019 with the UN Environment Programme allows players on the popular social media app Snapchat to see how their immediate environment (whatever they point their camera at) would look like given rising sea levels in 2100. The AR lens shows how much sea levels would rise every year between 2019 and 2100.[106]

[104] Stefan Brambilla Hall and Moritz Baier-Lentz, "3 technologies that will shape the future of the metaverse – and the human experience," World Economic Forum, February 7, 2022, https://www.weforum.org/agenda/2022/02/future-of-the-metaverse-vr-ar-and-brain-computer/.

[105] "After Ice is a New App That Uses AR to Simulate the Effects of Climate Change Around the World," 9to5Mac, https://9to5mac.com/2017/04/20/after-ice-ar-climate-change-simulator/.

[106] "New Snapchat AR Lens Shows You What Climate Change Can Do," WeRSM, https://wersm.com/new-snapchat-ar-lens-shows-you-what-climate-change-can-do/.

Photo by Patrick Schneider on Unsplash.

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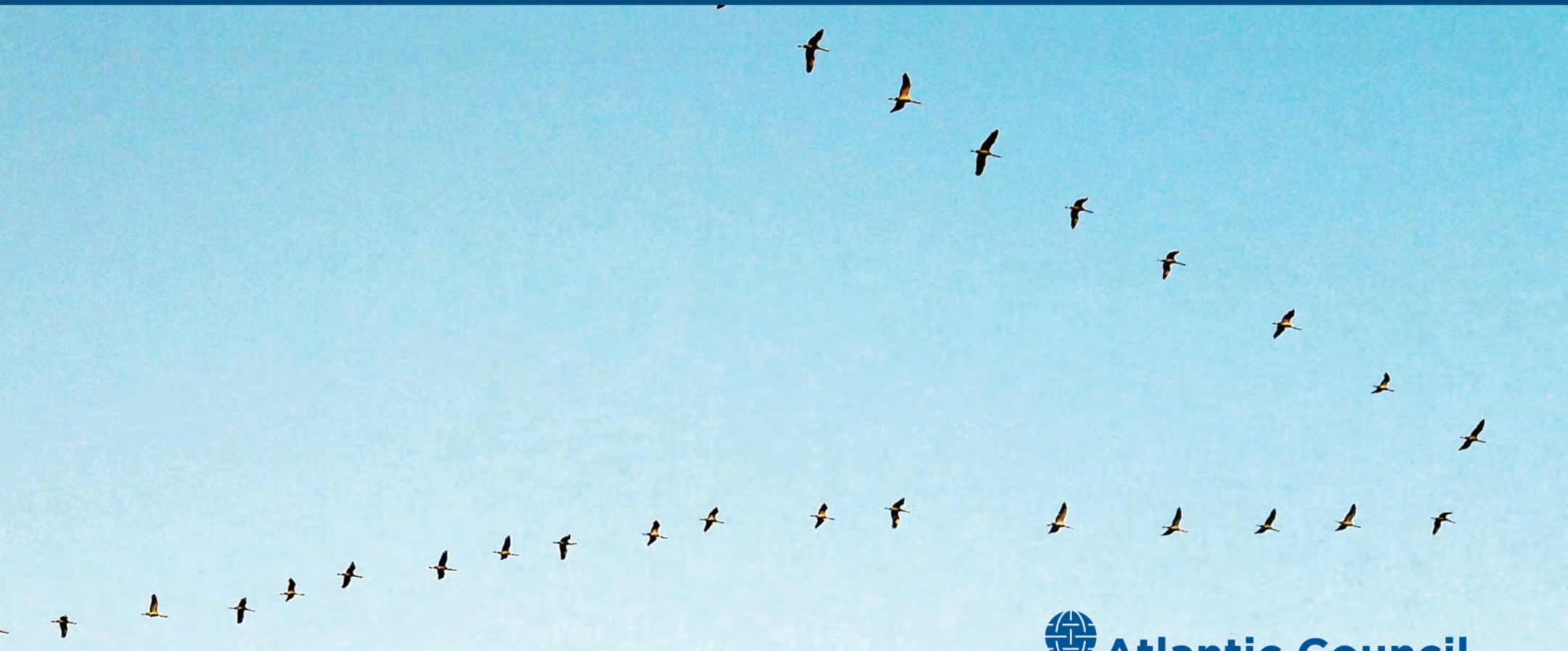
List as of April 14, 2022



Atlantic Council

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1030 15th Street, NW, 12th Floor, Washington, DC 20005
(202) 778-4952
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The future of our planet and humanity's wellbeing is in our hands.

Let's light a path towards a better future.

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