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Work-in-Progress—Visualising the Impacts of Climate Change with Immersive Technology

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Abstract. This work-in-progress paper analyses how immersive technologies can contribute to overcoming psychological barriers which impede behavioural changes that are needed in response to Climate Change. Although Climate Change poses immediate and long-term challenges to many aspects of our lives, these are often perceived as psychologically distant because they are communicated in abstract ways, which inhibits pro-environmental behaviour. Virtual Reality (VR) has the potential to address this psychological barrier by enabling people to directly experience the impacts of global warming and visualise them in concrete ways, which in turn can induce ecological behaviour.

Keywords: Climate Change, Global Warming, Virtual Reality, VR, Coastal Erosion, Flooding, Sea Level Rise.

1 Introduction

The predicted impacts of climate change on the world's cultural and natural heritage are considered by the international scientific community as *'one of the major challenges of the twenty-first century'* [1]. Anthropogenic factors have dramatically induced a warming climate, and a change in human behaviour is an essential part of the solution [2]. Research indicates that climate change information is often perceived as abstract by the public, a phenomenon known as psychological distance from climate change [3]. This acts as a barrier to the behavioural change needed from individuals, corporations, and institutions to slow down and limit global warming [3]. Information perceived as concrete is demonstrated to have a much bigger influence on human behaviour [4].

According to [5], environmental issues related to sea level rise are especially seen as psychologically distant since this is *'a slow and temporally distant process'* [5]. Scientists have discovered that mitigating psychological distance from climate change can induce pro-environmental behaviour in individuals [6]. Our research project investigates how to break down this perception barrier through the utilisation of immersive technologies to monitor and communicate the effects of climate change. We have begun this by developing Virtual Reality (VR) simulations that illustrate how climate change is expected to affect the future of some especially vulnerable areas, like Scotland's coastal environment which is expected to be damaged by coastal flooding & erosion [1,7-8] and Antarctica, which is the fastest warming region in the world [9].

2 Achieving Ecological Behaviour by Concretely Visualising Climate Change

Most digital developments that illustrate the impacts of climate change on coastal environments are in the form of coastal maps, such as the ones developed by the Scottish Environment Protection Agency (SEPA) [10], Dynamic Coast [11], and Climate Central [12]. These interactive tools are useful for researchers that want to assess future coastal changes, but are they effective communication tools to the public? To evaluate this, we

carried out an anonymous online survey with 42 global respondents. 67% of participants have not encountered any educational campaigns on coastal erosion, while 46% have not come across any informational initiatives regarding coastal flooding. Respondents were asked to evaluate the Dynamic Coast digital map and compare this with other coastal communication tools, such as VR and research papers. Only 23.8% of respondents preferred coastal maps, with further feedback stating that they are unappealing and hard to navigate. This suggests that coastal maps could reinforce how abstract climate information is perceived, enhancing psychological distance.

Virtual reality is an emerging form of visualisation that is defined as a computer-generated simulation in which the user can interact with an artificial three-dimensional environment using electronic devices, such as the computer keyboard and mouse, or a more sophisticated VR headset [13]. The goal is to help the user have a realistic-feeling experience, by engaging their vision, and sometimes touch [14]. VR has been described as the *'ultimate empathy machine'* as it enables users to feel closer to global issues, and it has been shown to reduce psychological distance from climate change [15]. Despite these advantages, there is only a limited number of such projects, and most of them incorporate expensive hardware, while also not being available online. Examples of projects that relate to polar climate change manifestations are Greenland Melting [16], which exhibits receding Arctic Ice, and Beyond the Diorama [17], which educates on how climate change will impact Arctic caribou populations. Despite Antarctica's tremendous significance for the global climate and its contribution to sea level rise [18], there are no climate change VR experiences that focus on the South Pole. What is more, there is only a small number of VR applications that illustrate sea level rise. One such project is called The Sea Level Rise Explorer, and it shows how coastal erosion and flooding will impact three American cities in 100 years [5]. Still, no VR projects relate to Scotland despite how vulnerable the country's shorelines are from coastal flooding and erosion.

This is still an underdeveloped research area that requires further technical, psychological, and social evaluation [15, 19]. We hope to address this by developing the first VR experiences that visualise how ecosystems in Scotland and Antarctica are expected to deteriorate as a result of global warming. So far, we have developed a prototype project focusing on how one of Scotland's most dynamic coasts, Tentsmuir Nature Reserve, is threatened by coastal flooding. The simulation can be downloaded from the project's web page that incorporates various visual artefacts by going to https://stage.openvirtualworlds.org/tentsmuirclimatechange/. A panoramic tour of the simulation can be found at https://kuula.co/post/Nh8vJ/collection/79rKH.

3 Methodology

The prototype project's purpose was to gain more understanding on how VR can facilitate a more engaging ecological learning experience, more specifically when applied to coastal changes. We also wanted to assess current public perception on these environmental matters, and therefore collected primary qualitative data through a survey titled '*Public awareness of climate change manifestations on coastal habitats'* before the development of our VR application. The survey can be accessed by going to the following link: https://standrews.eu.qualtrics.com/jfe/form/SV_816Lwl5mLuxGFIa.

This consisted of seven *'Yes'* or *'No'* questions, one nominal question, and one open-ended question. It was an online anonymous survey with no time limit that was advertised on LinkedIn, with the aim to be completed by at least 30 individuals. Finally, results were analysed from 42 global respondents who fully completed the survey. To instruct the development of the virtual environment, we gathered on-site experience and visual materials of Tentsmuir Nature Reserve. Secondary elevation data for the region were imported into the game engine utilised to create the VR application, ensuring an accurate representation of the terrain and water levels. To inform the simulation of the future level of flooding, various research sources related to coastal erosion and flooding were utilised, such as scientific papers, climate models and digital coastal screening tools. After finalising the virtual simulation and creating the project's web page, six students from randomised departments across our university were asked to evaluate the project.

We then collected primary feedback data from them using an anonymous survey without a time limit that can be accessed by visiting https://standrews.eu.qualtrics.com/jfe/form/SV_esuplUoHxwNnWxo, titled '*The Future of Climate Change on Scotland's Coasts: A look into Tentsmuir National Nature Reserve.'* This included seven rating scale questions. As both surveys were conducted with Qualtrics, the built-in results-analytics feature was used to evaluate the responses since it divided answers into clear categories. The prototype project was developed during the Covid-19 pandemic, and these research methods were some of the few available tools that enabled us to safely gather responses and feedback from various global respondents to gain a wider public perception on the matters analysed.

4 Design and Implementation

Game engines like Unreal Engine (UE) or Unity can be used to create climate simulations. A 3D terrain model of the desired area is inputted into the game engine, which will accurately set the levels of the virtual landscape. Then the environment is modelled to resemble the selected region, and programmed to simulate how the habitat is expected to change in the future when a specific keyboard button is clicked. Unreal Engine was used to develop the virtual tour of Tentsmuir as it can render more realistic visualisations compared to Unity, which can be more useful in training and education [20].

A 3D terrain model based on an elevation map of Tentsmuir beach was inputted into the game engine so that the simulation accurately depicted the Nature Reserve. To achieve this, elevation data was downloaded from Digimap and processed into a terrain map in QGIS. This was then inserted into World Machine, a 3D landscape modelling software, to generate a high-resolution 3D terrain of Tentsmuir that was compatible with Unreal Engine. Brushify, an Unreal Engine design and environment toolkit was used to assemble the forest and coastline materials into the 3D environment, which were utilised to design the virtual environment so that it resembled Tentsmuir Nature Reserve. The user can walk and fly in the virtual landscape and control the flooding of the environment by pressing the G and H keys on the keyboard. This enables participants to easily compare the present environment with how it is expected to flood in the future. The visualisation was built in First-Person perspective, as this has been demonstrated to facilitate user engagement within virtual environments [21]. First-Person perspective was also implemented to enhance the Experience-Perception Link analysed by [5], i.e., that directly experiencing an environmental issue leads to greater behaviour and attitude change compared to second-hand information.

The final exhibition of the project is in the form of a web page, which was built with WordPress. We created a website as this is a universal communication method that has cross-platform capabilities. Also, more than half of the world's population (51.4%) has access to the internet [22]. The website further serves as an accessible platform where individuals could download the UE application from, and where the other visual tools could be assembled. These include a spherical photographic tour of Tentsmuir composed of panoramic images shot with the Insta360 Pro 2 omnidirectional camera. The images were embedded using the Insta360 Stitcher and another processing tool called Kuula. Spherical images from the UE simulation were also included after being taken using an Unreal plugin called NVIDIA Ansel. The usage of a bundle of visual communication methods was motivated by how powerful visualisation has proven to be in communicating the impacts of climate change and influencing pro-environmental behaviour. Another important reason for including these tools was the goal of creating a self-sufficient online exhibition in case some users would not want to investigate the links on the web page or download the Unreal Engine tour.

Although our prototype project deepened our understanding about how VR can help climate communication, it poses important limitations. The simulation only illustrates a single aspect of climate change (flooding) instead of the accumulation of simultaneous effects that would occur, such as extreme weather events, and changes in fauna & flora. It is a small-scale research project developed during the pandemic, and therefore evaluated by a limited number of participants from a similar age group (20-27). The project only assessed whether it provided an engaging learning experience, without analysing behaviour change. To address these limitations, we are amending our methodology and investigating two new use cases – North Uist, an isle located in the Outer Hebrides region in Scotland that is especially vulnerable to flooding events and coastal erosion [23], and Paradise Bay, which is a harbour located in the Western Antarctic Peninsula that is experiencing a tremendous climatic and biological response to global warming [9].

These visualisations will consist of multiple scenarios depicting the numerous simultaneous changes predicted in these areas, which are informed by the leading research in the fields of climate change, environmental science and marine biology. To achieve this, we are collaborating with experts from the School of Biology and the School of Earth and Environmental Science at the University of St Andrews. We will also develop an interactive storytelling gamified experience using the same game engine that depicts the connection between the global and local impacts of climate change, specifically how glacial meltwater from Antarctica induces sea level rise and extreme weather in Scotland. To enhance cross-platform capabilities and accessibility, we will create an online exhibition through a new web page, while using the newest release of Unreal Engine to develop versions of the simulations that will be suitable for both computers and VR headsets. So far, we have developed the initial version of the North Uist simulation using Unreal Engine 5, modelling how its capital area is expected to flood during an extreme storm event, which already includes more elements than the Tentsmuir tour. We have also built a virtual environment of Paradise Bay in its present state, which will be further modelled to visualise the future impacts of climate change in this vulnerable region.

5 Testing and Evaluation

As processing power can affect the performance of Unreal Engine simulations, the Tentmsuir application was successfully tested on several Desktop machines available at our academic institution. We then asked two random students to download the application on their personal Lenovo laptops. The application worked well on both computers, but the character movement was slower due to the laptops' lack of gaming performance. We also asked six random members from our academic institution to review our web page and assess the UE simulation using one of the Desktop computers available in one of our workspaces. In the feedback survey, all individuals strongly agreed that the website was engaging and easy to navigate. Furthermore, the visual tools created a more fascinating learning experience for them. Every participant strongly agreed that the VR simulation was intuitive to use, that it sparked involvement and facilitated a more enjoyable learning experience. This corroborates the research analysed in this paper and indicates that Climate Change Virtual Reality is a promising area that could provide an efficient communication tool for raising ecological awareness and influencing pro-environmental behaviour.

With the North Uist project being in its initial stage of development, we asked 35+ people within and beyond our academic institution to assess the simulation. After testing it on a machine available in our laboratory, the participants offered their feedback through a questionnaire. The results further support that Virtual Reality is an engaging way of ecological learning. The main points we were asked to improve, which we are addressing during the ongoing development of this project, are to add more realistic details to the environment, to build multiple climate change scenes, and to show relevant metrics on the screen, such as water levels and rainfall. We are currently focusing on making the visualisation more realistic by reconstructing some weather elements (sky, wind, water movement) and by adding sound to depict a more accurate storm experience. After this development phase is completed, we will host an exhibition in North Uist and gather feedback from locals. This is important as we aim to improve our evaluation processes and collaborate with both local and global audiences to evaluate the projects. We aim to collect feedback from individuals that have been to Antarctica and North Uist so we can analyse if there are any differences in the perception of people who have previously visited these regions. To extend our reach, we will cooperate with Antarctic expeditions groups and Scottish organisations, as they play important roles in the climate movement. Furthermore, we will embed several calls-to-action into the final website, such as links to relevant charities and petitions. In this way, we can evaluate how many individuals engage with the exhibition in a way that impacts behaviour.

At the end of this research project, we aim to develop a revolutionised framework on how to use VR for climate communication that can be implemented by other groups and organisations for visualising the future changes in their local regions.

6 Final Remarks

Our findings corroborate the research currently available on Climate Change Virtual Reality. Our prototype project indicates that VR could complement other climate communication tools by significantly impacting public perception and pro-environmental behaviour. Our ongoing research hopes to progress the field of Climate Change Virtual Reality, and instigate more scientists to investigate this promising, yet underdeveloped field.

Fig. 1. Image of the Paradise Bay UE Virtual Environment in its current state of development.

References

1. UNESCO: Case studies on climate change and world heritage. UNESCO Digital Library, vol. 42 (2007).
2. Steffen, W., Rockstrom, J., Richardson, K. et al.: Trajectories of the Earth System in the Anthropocene. In: Proceedings of the National Academy of Sciences of the United States of America, vol. 115, pp. 8252–8259 (2018). doi:10.1073/pnas.1810141115
3. van Lange, P., Bastian, B.: Reducing climate change by making it less abstract. In: Scientific American, 320(4). Nature Publishing Group (2019).
4. Borgida, E., Nisbett, R.: The differential impact of abstract vs. concrete information on decisions. In: Journal of Applied Social Psychology, vol. 7, pp. 258 – 271 (2006).
5. Calil, J., Fauville, G., Queiroz, A. C. et al.: Using virtual reality in sea level rise planning and community engagement-an overview. In: Water, vol. 13, p. 1142 (2021).
6. Wang, S., Hurlstone, M., Leviston, Z., Walker, I., Lawrence, C.: Climate change from a distance: An analysis of construal level and psychological distance from climate change. In: Frontiers in Psychology, vol. 10, p. 230 (2019).
7. Sub-Committee of the Committee on Climate Change: UK Climate Change Risk Assessment 2017 Evidence Report – Summary for Scotland. In: UK Climate Change Risk Assessment (2017).
8. Hansom, J., Fitton, J., Rennie, A.: Dynamic Coast - National Coastal Change Assessment: Summary. In: The National Coastal Change Assessment Reports (2017).
9. Mulvaney, R., Abram, N., Hindmarsh, R. et al.: Recent Antarctic peninsula warming relative to Holocene climate and ice-shelf history. In: Nature, vol. 489, pp. 141–144 (2012). doi: 10.1038/nature11391.
10. Scottish Environment Protection Agency: Flood risk management maps. https://map.sepa.org.uk/floodmap/map.htm
11. Dynamic Coast: Compare your future coasts. https://www.arcgis.com/apps/dashboards/defe901982154099b6ceb19db8aa41a4,
12. Climate Central: Coastal risk screening tool. https://coastal.climatecentral.org/map/12/-2.693/56.4303/?theme=sea_level_rise&map_type=year&basemap=roadmap&contiguous=true&elevation_model=best_available&forecast_year=2050&pathway=ssp3rcp70&percentile=p50&return_level=return_level_1&rl_model=gtsr&slr_model=ipcc_(2021).
13. Lowood, H. E.: Virtual reality. https://www.britannica.com/technology/virtual-reality
14. Metcalfe, T.: Virtual reality. https://www.nbcnews.com/mach/science/what-vr-devices-apps-turn-real-world-virtual-ncna857001
15. Markowitz, D. Bailenson, J.: Virtual reality and the psychology of climate change. In: Current Opinion in Psychology, vol. 42, pp. 60-65 (2021). doi: 10.1016/j.copsyc.2021.03.009
16. NOVA, Frontline: Greenland melting. https://store.steampowered.com/app/1012510/Greenland_Melting/
17. Lindberg, E.: Stunning virtual reality project takes you to the arctic — and into climate change. https://news.usc.edu/trojan-family/usc-virtual-reality-climate-environmental-education/.
18. NASA: Nasa-led study reveals the causes of sea level rise since 1900. https://climate.nasa.gov/news/3012/nasa-led-study-reveals-the-causes-of-sea-level-rise-since-1900//
19. Queiroz, A. C., Kamarainen, A., Preston, N., da Silva Leme, M.: Immersive virtual environments and climate change engagement. Conference: Immersive Learning Research Network (2018). doi: 10.3217/978-3-85125-609-3.
20. Checa, D., Bustillo, A.: A review of immersive virtual reality serious games to enhance learning and training. In: Multimedia Tools and Applications, vol. 79, pp. 5501-5527 (2020). doi: 10.1007/s11042-019-08348-9.
21. Gorisse, G., Christmann, O., Amato, E., Richir, S.: First- and third-person perspectives in immersive virtual environments: Presence and performance analysis of embodied users. In: Frontiers in Robotics and AI, vol. 4, p. 33 (2017). doi: 10.3389/frobt.2017.00033.
22. Statista: Percentage of global population accessing the internet from 2005 to 2021, by market maturity. https://www.statista.com/statistics/209096/share-of-internet-users-in-the-total-world-population-since-2006/.
23. Scottish Environment Protection Agency: Flood risk management plan - Outer Hebrides local plan district (2021).