

What Is the Role of Museums and Meaningful Extended Reality Experiences in Supporting Mental Health and Well-Being in Space? The Place in Space of Cultural and Heritage-Based Extended Reality Experiences

By Kaja Antlej, Annahita Nezami, Bahareh Nakisa, Kaori Becerril, and Sylvester Arnab

Abstract

This paper proposes that museums and other heritage institutions can play an important role in supporting the psychological, social and emotional needs of professional astronauts as well as people living and working in isolated, confined and extreme environments of space, including on space stations, the Moon and Mars. The authors present a summary of a research study proposal that looks to explore how a dual-purpose astronomical heritage extended reality application, leveraging affective computing techniques, can support the wellbeing of spacefarers. Can meaningful and engaging immersive experiences assist in minimising loneliness and homesickness? Can such experiences motivate astronauts to exercise? An international transdisciplinary team of researchers proposes a holistic approach to overcoming the mental health and wellbeing challenges of long-duration space missions by combining astronomical heritage content with affective-computing techniques (wearable sensors and artificial intelligence) to monitor and treat emotional states of astronauts.

Keywords: Museums, Heritage, Human Space Exploration, Deep Space, Mental Health, Well-Being, Extended Reality, Virtual Reality, Astronomical Heritage, Overview Effect.

Introduction

Digital transformation, advanced manufacturing, and Industry 4.0 are critical enablers of the entrepreneurial innovation-driven movement of NewSpace. These efforts have helped to democratise the previously closed space sector.¹ Morgan Stanley research forecasts that the global space sector may increase to more than \$1T by 2040.² Among downstream applications related to space data utilisation for communications, Earth observation and navigation, several planned scientific and economic upstream activities such as in-space manufacturing in low gravity and resource utilisation are planned. The

¹ Robert C. Jacobson, *Space Is Open for Business: The Industry That Can Transform Humanity* (Los Angeles: Robert Jacobson, 2020); Alastair Storm Browne and Maryann Karinch, *Cosmic Careers: Exploring the Universe of Opportunities in the Space Industries* (Nashville: HarperCollins Leadership, 2021).

² Morgan Stanley, "Space: Investing in the Final Frontier," July 24, 2020, www.morganstanley.com/ideas/investing-in-space/.

latest activities may require long-duration *human* space missions to low Earth orbit (LEO), as well as to outer space, including the Moon and Mars.³

Human space exploration presents not only technical challenges, but also health and well-being-associated concerns from both physiological and psychological perspectives. For example, besides behavioural and cognitive changes because of long-duration living and working in isolated, confined and extreme (ICE) environments, weakening and deterioration of muscles in low gravity is one of the most prevailing concerns of human space exploration. As a countermeasure, astronauts on the International Space Station (ISS) spend 2.5 hours per day exercising.⁴

Exercising in ICE may also be challenging from the motivational point of view. Virtual reality is an effective and feasible psychological tool that can support wellbeing initiatives. Emerging research from analogue missions has shown that nature-based virtual reality experiences are restorative and help to improve the mood of people living in ICE.⁵ With this in mind, space agencies are now exploring how restorative extended reality (XR) environments can increase exercise motivation.⁶

Museums in the Era of Space Exploration

In relation to human spaceflight, until recently, museums were places to collect and exhibit space-related objects, including technical heritage and memorabilia. Considering audience engagement, the main purpose of space museums is still often seen as being a vehicle for science, technology, engineering and mathematics (STEM) outreach. There is no doubt that museum exhibitions and natural sites of heritage play a significant role in inspiring visitors and cementing our cultural legacy here on Earth.

Alongside traditional space museums and science centres, new initiatives are emerging that are focused on preserving both geological and human heritage in outer space and on celestial bodies to inspire future generations and to ensure a sustainable environment.⁷ For example, the American Alliance of Museums' special issue of *Museum 2040* from 2017 featured two space-related initiatives: a pop-up intergalactic museum

³ Namrata Goswami and Peter A. Garretson, *Scramble for the Skies: The Great Power Competition to Control the Resources of Outer Space* (Lanham: Rowman & Littlefield, 2020).

⁴ National Aeronautics and Space Administration, "NASA Information: Muscle Atrophy," accessed March 10, 2022, www.nasa.gov/pdf/64249main_ffs_factsheets_hbp_atrophy.pdf.

⁵ Allison P. Anderson, Michael D. Mayer, Abigail M. Fellows, Devin R. Cowan, Mark T. Hegel, and Jay C. Buckley, "Relaxation with Immersive Natural Scenes Presented Using Virtual Reality," *Aerospace Medicine and Human Performance* 88, no. 6 (2017): 520–26, doi.org/10.3357/AMHP.4747.2017.

⁶ Melissa Gaskill, "Nine Ways We Use AR and VR on the International Space Station," NASA, September 24, 2021, www.nasa.gov/mission_pages/station/research/news/nine-ways-we-use-ar-vr-on-iss.

⁷ Alice Gorman, *Dr. Space Junk vs. the Universe: Archaeology and the Future* (Cambridge, MA: MIT Press, 2019); Roy Balleste and Michelle L. D. Hanlon, "How Blockchain Technology Can Track Humanity's Lunar Heritage Sites," *Space Review*, June 11, 2018, thespacereview.com/article/3512/1.

and a satellite collection storage system aiming to protect and preserve museum objects from the potential consequences of climate change on Earth.⁸

How can museums and other galleries, libraries, archives and museums (GLAM institutions) become more directly involved in human space exploration and even support people living and working off Earth, on the space stations, the Moon or Mars? Similarly, as it stands, travel to Mars itself will require at least seven months of isolation in a confined space, with even more severe psychological challenges when both our home planet and the red planet will be almost out of sight.

As per the current museum definition by the International Council of Museums (ICOM) from 2007:

A museum is a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment.⁹

It is essential to point out that a new definition is currently being developed as a response to the constantly evolving role of museums in society. The development of a new definition started before the global COVID-19 pandemic. After the initial controversy and the rejection of the first proposed definition, the new strategy is now a consultation approach of four cycles. Regardless of the results, it will be interesting to see how future-oriented the new museum definition will be and how well it will be aligned with the current progress towards the growing spacefaring aspirations. How can museums serve future generations of human beings living and working on and off the Earth? Will or should off-Earth museums merge with other GLAM institutions to provide a place for enhancing and maintaining inspiration, curiosity and discovery, like the Great Library and Alexandrian Museum (*Mouseion*) in Ancient Egypt?¹⁰

Consultation 2 ended in June 2021, and it defined the keywords to include in the definition. Its questions included what is a museum, what is its function and role and who is its target audience? Consultation 2 utilised the dimensions laid out by analysts: entity (what a museum is), entity qualifier (what qualifies a museum), object/subject (what are the museums' objects/subjects), action/function (what a museum does), experience (what do people experience at a museum), social values (what values shape museums) and target and relationship (who museums work for and the nature of their relationship).

⁸ American Alliance of Museums, *Museum 2040* 96, no. 6 (November/December 2017), www.aam-us.org/wp-content/uploads/2018/04/museum2040.pdf.

⁹ International Council of Museums, "Museum Definition," accessed March 10, 2022, icom.museum/en/resources/standards-guidelines/museum-definition/.

¹⁰ Mostafa El-Abbadi, "Library of Alexandria," *Britannica*, July 17, 2020, www.britannica.com/topic/Library-of-Alexandria.

The results of Consultation 2 (ninety-six responses from 178 committees) proposed the main keywords and concepts that the museum definition should include. For example, on the function and role of a museum, besides research and preservation, most respondents believed that museums also serve as collection and exhibition hubs. Other frequently mentioned terms were communication, interpretation, acquisition, safeguarding and documentation. In relation to the question of what people experience at a museum, education was the most mentioned term, followed by knowledge, dialogue and enjoyment or entertainment. Interestingly, a significant number of respondents (17%) believed that museums contribute to well-being. This highlights that museums potentially play an important role in maintaining social wellbeing in society today. Emerging research supports the view that museum and natural heritage experiences promote wellbeing.¹¹ In the 2022 TrendsWatch report from the American Alliance of Museums, mental health was listed as one of “the five pillars of community strength and resilience” that museums provide along with education for our children, liveable communities for our elders, emergency response in the face of disasters and a human-centred culture of sustainability.¹²

Considering the health and well-being benefits of museums, we suggest that museum and heritage-based experiences will assist spacefarers and dwellers alike to feel a sense of belonging to their home planet and more connected with the natural world. But what kind of heritage? Whose heritage? As per UNESCO,

Heritage is our legacy from the past, what we live with today, and what we pass on to future generations. Our cultural and natural heritage are both irreplaceable sources of life and inspiration.¹³

Heritage can be divided into tangible and intangible heritage. Material heritage is further divided into movable and immovable heritage. Movable heritage is the objects we usually find in museums. Immovable heritage mainly covers buildings, archaeological sites and land. A relatively new concept is intangible heritage, such as traditions, performing arts, and knowledge and skills. To understand better what heritage XR content may be most suitable for assisting humans in space, including our astronomical heritage, the team is consulting heritage institutions as well as Indigenous communities.

Mental Health and Wellbeing in Space

Our initiative addresses the health and well-being challenges of human space exploration through a transdisciplinary approach from both STEM and humanities and

¹¹ John H. Falk, *The Value of Museums: Enhancing Societal Well-Being* (Lanham: Rowman & Littlefield, 2021).

¹² Center for the Future of Museums, *TrendsWatch 2022* (Washington, DC: American Alliance of Museums, March 2022).

¹³ UNESCO, “World Heritage,” accessed March 30, 2022, whc.unesco.org/en/about/.

social science disciplines. Specifically, we are aiming to support the endeavours of space medicine by applying space psychology, engineering, IT (including XR and artificial intelligence [AI]), human-centred design, game design (space design) and digital heritage to innovative solutions that will directly benefit astronauts and people living and working off Earth.

In Australia, space medicine is a well-developed discipline. In late 2021, the House of Representatives Standing Committee on Industry, Innovation, Science and Resources released a 246-page Parliamentary Space Industry Report, *The Now Frontier: Developing Australia's Space Industry* containing thirty-eight recommendations on how the Australian Government can support this rapidly growing sector. Leveraging extensive Australian expertise in remote medicine supporting communities in rural Australia and in Antarctic bases, *Recommendation 20* proposes to "examine ways to better support and coordinate space medicine research, training and development to ensure that the translational benefits of aerospace medicine can be applied on Earth".¹⁴ Space medicine and human factors are also among the priorities of *A Decadal Plan for Australian Space Science 2021–2030*.¹⁵

Besides the alignment with the current strategy of the Australian space sector, our study was inspired by the Overview Effect, a term coined by space philosopher Frank White to refer to the experience of seeing planet Earth first hand from a panoptic perspective, and *EPIC Resilience*, meaning emotional, physical, intellectual, and creative resilience.¹⁶ Our proposal also integrates indigenous systems of knowledge and a First Nations holistic approach to heritage, health and wellbeing in collaboration with Deakin University's National Indigenous Knowledges Education Research Innovation Institute and its newly established Indigenous Knowledge Systems Lab.

On the one hand, immersive and gamified heritage experiences can promote better engagement in fitness activity embedded within the context of the environment and interactivity. The heritage aspect will help to promote relatability and emotional connection. Aligning with self-determination theory, motivation is linked to autonomy, relatedness and competence. The competence lies in the gamified challenges that the environment will facilitate, aligning with the fitness requirements. Furthermore, museum

¹⁴ Parliament of the Commonwealth of Australia, House of Representatives Standing Committee on Industry, Innovation, Science and Resources, *The Now Frontier: Developing Australia's Space Industry* (Canberra: Commonwealth of Australia, 2021), parlinfo.aph.gov.au/parlInfo/download/committees/reportrep/024732/toc.pdf/TheNowFrontierDevelopingAustralia'sSpaceIndustry.pdf;fileType=application%2Fpdf.

¹⁵ National Committee for Space and Radio Science, *Australia in Space: A Decadal Plan for Australian Space Science 2021–2030* (Canberra: Australian Academy of Science, 2022), www.science.org.au/files/userfiles/support/reports-and-plans/2022/australia-in-space-a-decadal-plan-for-australian-space-science-2021-2030.pdf.

¹⁶ Sally Dominguez, *EPIC Resilience: Thriving Through Chaos and Change* (Corte Madera, CA: Adventurous Thinking Group, 2021).

and heritage experiences, as well as motivational factors, are aligned with self-determination theory, which is often adopted in game-based and game-like experiences.

Research Proposal

As a part of the initiative, various research projects are currently under development with different partners, including museums and indigenous organisations. To validate the types of immersive heritage content that are most suitable, the design and development of an AI-supported real-time monitoring system to detect the emotional states and wellbeing of astronauts using lightweight wearable sensors is proposed.

The initial data collection will be carried out in a museum setting using a citizen science approach in which museum visitors will be immersed in an XR experience. It is important to point out that this strategy is another way that museums can directly contribute to human space exploration research to improve the lives of astronauts. The second data collection will target the participants at preidentified analogue mission sites in Australia and the United States. The third set of data will be collected at the ISS or a similar environment in a microgravity off Earth.

We are not aiming to develop the mechanical part of the exercise equipment *per se*. However, we intend to team up with and support those who are specialising in this field with a meaningful XR content and a measuring and monitoring system to provide the best immersive experience.

The research questions (RQ) below have been proposed to guide the development of holistic solutions through collaborative transdisciplinary partnerships:

RQ1: How can game-like XR experiences supported by GLAM/heritage institutions fulfil the cognitive and mental health needs of astronauts and people living and working off world, beyond LEO?

RQ2: Can engaging and meaningful content assist people to develop a stronger sense of belonging and connection with the Earth (home)?

RQ3: Can game-like heritage XR content increase motivation for interacting with the monotonous exercise equipment installed in an ICE environment?

RQ4: Can AI and wearable sensors measure the emotions of users and monitor their wellbeing?

Conclusion

The proposed study will contribute to our understanding of how game-like immersive heritage experiences can support the mental health and well-being of not only astronauts, but also, as a space spin-off, people on Earth. The scope of applications like this is wide, extending out to hospitals, asylums, retirement villages, prisons and other isolated living

and working environments such as in Antarctica, oil rigs, mines and remote areas. Our study also aligns with the UN Sustainable Development Goals, e.g., 3—Good Health and Well-Being.¹⁷ The COVID-19 pandemic is a global event that exposed us all to highly stressful conditions and highlighted the importance of maintaining mental health and well-being while being isolated in (more or less) confined spaces for long periods of time.

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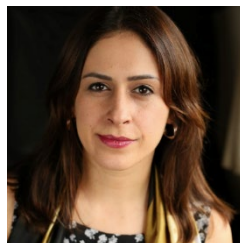
Editors' Notes: Like the previous paper, this article brings a new perspective to the *Journal of Space Philosophy*. Antlej et al., an interdisciplinary team of researchers, consider the potential role of museums (and similar cultural installations) in supporting well-being in space. As the very nature of museums and curated cultural experiences are changing on Earth (often becoming far more embedded and interactive), the authors suggest that protecting and transmitting heritage in space communities or even very small living spaces, may be important for the health of those who have migrated off Earth. This is a valuable perspective to keep in mind for the space architects and spacecraft interior designers of the future—and those already working in 2022. ***Gordon Arthur and Mark Wagner.***

¹⁷ United Nations, Department of Economic and Social Affairs, Sustainable Development, "The 17 Goals," accessed March 10, 2022, sdgs.un.org/goals.

About the Authors



Dr. Kaja Antlej is a researcher working in the intersection of human-centred design, digital heritage and virtual museums, extended reality, 3D printing, futures thinking, entrepreneurship and space. Kaja obtained her BSc/MSc (2008) in Industrial Design and a PhD (2013) in Museum and Heritage Studies at the University of Ljubljana and is currently working as a Senior Lecturer in Industrial Design and CADET Virtual Reality Lab Researcher—Museums/Heritage at the School of Engineering, Deakin University in Geelong, a UNESCO City of Design, Australia. Between 2013 and 2014 she was a European Voluntary Service volunteer in Rabat/Casablanca, Morocco, and completed a four-month entrepreneurship training at RRA LUR in Slovenia. Prior to moving to Australia after receiving a prestigious Endeavour Postdoctoral Fellow 2015 by the Australian Government, Kaja worked on several EU-funded projects. She is an alumna of the Southern Hemisphere Space Studies Program 2021 at the International Space University and the University of South Australia, an Expert Member of the Committee for the Cultural Utilisation of Space, a technical committee of the International Astronautical Federation and a member of the Space Industry Association of Australia. Dr Kaja Antlej is the Co-founder and President of the Slovenian Australian Academic Association and a member of several museum/heritage organisations including ICOM, AMaGA, AAM, MuseWeb and Interpret Europe.



Dr. Annahita Nezami is the founder of VROE, an international speaker, researcher, and chartered psychologist providing consultation, training, and therapy. Her areas of interest include space health and the Overview Effect, wellbeing, neuroscience, trauma, depression, performance and altered states of consciousness. Annahita serves as an advisor to multiple organisations and was elected as a fellow of the Royal Society for the Encouragement of Arts, Manufactures and Commerce. She has been a guest lecturer at various establishments such as Deakin University, Australia, Central St Martin's, London,

and University College, London; she was invited to talk about mental health and the Overview Effect on BBC Radio 4 and TEDx; and she has published papers and articles with Springer and other media outlets.



Dr. Bahareh Nakisa is a Lecturer of Applied AI and the Course Director of Applied AI at the School of Information Technology, Deakin University, Australia. She received a BSc degree in Soft Engineering from Iran in 2008, Master of Computer Science from the National University of Malaysia in 2014, and a PhD in Computer Science (AI) from Queensland University of Technology, Australia in 2019. She started working in industry as AI scientist and lead AI scientist, and then she joined the School of Information Technology, Deakin University as a Lecturer of Applied AI in 2019. Her research spans a broad range of topics related to AI, machine learning and deep learning. She has applied analytic and algorithmic tools from these fields to solve real-world problems related to diverse domains, especially in health and affective computing.



Kaori Becerril is an Industrial Designer from the National Autonomous University of Mexico (UNAM). She is currently Chief Design Officer in Dereum Labs. She was invited to be a panellist and a mentor at the NASA Space Apps Challenge, and she participated in Space Up Mexico 2019. She was a facilitator during the “Design in Space for Life on Earth Challenge” organised by the World Design Organization and the ISS National Lab. She was a volunteer at the Moon Village Association Lunar Commerce and Economics working group and a member of the organising team for the “Towards a Lunar Generation Workshop 2021.” She was a delegate member for the NCAC Space Generation Online Workshop 2020, a delegate for the Space Generation Fusion Forum 2021 and a member of the Architecture Team for the DIA Project from the Space Generation Advisory Council. She was an author at the IAC 2021 “Strategic Design for Space Business: A Different Approach” and the organiser and moderator of “Co-Create the New Space Economy,” a futuring workshop at ASCEND.



Sylvester Arnab is a Professor of Game Science at the Disruptive Media Learning Lab and an associate of the Centre for Post-Digital Cultures at Coventry University, UK. His research focuses on the investigation into engaging, empathic, and empowering experiences through the lens of playful and gameful design practices. Sylvester is a co-founder of the multi-award winning GameChangers initiative (gamify.org.uk), focusing on playful and gameful learning experiences, which has been adapted in Malaysia and is currently being expanded into Vietnam and Indonesia towards responding to the UN's Sustainable Development Goals. GameChangers has also informed the Beaconing Project (beaconing.eu), which was led by Sylvester and is often referred to as a best practice for gamified learning in Europe. To date, Sylvester has successfully won research funding with a total value of £19 million since 2010 (£9.9 million as a principal investigator). Funders include the UKRI (AHRC and ESRC), European Commission (FP7, H2020 and Erasmus+), and HEFCE. Sylvester has over 100 academic publications, having recently published a book on *Game Science in Hybrid Learning Spaces*, which provides insights into the research and practice of purposeful game design with a focus on hybrid education.