Scoping Review

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MSc. Extreme Medicine

Virtual Reality in Analog Space Missions

Analog space missions are simulated space environments on Earth that mimic the physical and psychological conditions of space travel, used for research and training purposes.
Virtual reality (VR) is an immersive digital technology that simulates a three-dimensional environment, allowing users to interact with a seemingly real world.

Space is the ultimate frontier, pushing human endurance and medical expertise to the limits.
Analog space missions are therefore crucial for advancing the field of extreme medicine. With Virtual Reality revolutionizing research, making it more efficient and immersive, discover how these innovations are propelling us toward the future of space exploration and groundbreaking medical advancements.

Methods

- **Bibliographic database searched:** Web of Science
- **Grey literature:** National space agencies

- **Inclusion criteria:**
  - Use of Virtual Reality or Augmented Reality
  - Focus on Analog Astronauts
  - Analog Space Missions
  - Literature in English language

- **Exclusion criteria:**
  - Non interactive computer simulations
  - Focus on Analog mission organisation team
  - Space missions
  - No date restriction

Results

- **Literature found:** 22
  - Web of Science: 21
  - Grey literature: 1
- **Published after 2018:** 91%
- **Financed by NASA:** 32%
- **Type of analog:**
  - Microgravity: 77%
  - ICE: 27%
- **Most used VR hardware:**
  - HTC: 18%
  - Oculus Rift: 14%
- **VR as the focus of a study:** 55%
- **VR as a support in a study:** 45%
- **Economic benefit of using VR:** 5%
- **Parabolic flight:** 18%
- **Nausea occurred in:** 23%
- **Sample sizes:** 1 - 60
- An overview of all the literature available on the cards below. Note that some studies do not specifically address VR, as Virtual Reality was only used as a support tool in those cases.

Discussion

Three main points of this work are:

- Literature on this topic is still relatively scarce
- Almost all of the literature has been published in the last 5 years
- NASA (USA) is most progressive in this field

Among the various aspects of the space environment, microgravity is the most commonly simulated in analogs, typically through parabolic flights.
Some studies discuss the economic benefits of using virtual reality (VR) in space analogs, but the majority have failed to demonstrate this clearly.
A significant weakness of these studies, as acknowledged by the authors themselves, is the small sample sizes, which are rarely larger than twelve participants.
The VR hardware used in these studies primarily comes from the video game industry.
Despite the limitations, the authors generally agree that using VR in space analogs is beneficial.
I am confident that the amount of literature on this topic will increase significantly in the near future.



Microgravity analogs 77%



91% published after 2018



32% financed by NASA

M Microgravity
I Isolation Confinement Extreme (ICE)
O Other

Type of analog

Funding
NASA
Europe
Asia
Other (n/a, multinational)

I acknowledge a potential conflict of interest due to my role as a medical officer in Project Hydronaut, which focuses on isolation experiments in extreme environments within space analog missions.
I have received no funding for this review from Project Hydronaut.

Aim (I)
Communication limitations and options to combat behavioral threats in long duration missions
Findings
Virtual environments can improve social connectedness vs email
Wu (2016)
10.1016/j.proeng.2016.08.132

Aim (I)
Effectiveness of attention-restoration-therapy-based immersive VR in ICE environments
Findings
Natural scene VR was broadly considered restorative
Anderson (2022)
10.1177/00187208221100693

Aim (O)
Mars Planet Research Group's activities related to VR/AR in space mission simulations
Findings
VR/AR is effective for studying human behavior in space missions
Del Mastro (2021)
10.1016/j.jsse.2021.03.002

Aim (M)
Illustrate the limitations of underwater neutral buoyancy as a microgravity analog
Findings
Neutral buoyancy has limitations as a microgravity analog
Bury (2023)
10.1038/s41526-023-00282-3

Aim (M)
Outline the facilities, training curricula, and future aspirations for Blue Abyss
Findings
Complex training facilities will enable productive spaceflight operations
Pletser (2019)
10.1089/space.2019.0019

Aim (M/I)
Framework for clinical trials on inter planetary missions to innovate clinical trials on Earth
Findings
Identified key areas for clinical trial planning in space missions
Nasser (2020)
10.1111/jebm.12391

Aim (M)
Efficient system for gait evaluation in hypogravity
Findings
Hypogravity simulation reduces walking effort and the virtual environment reduces postural balance
Leães (2006)
n/a

Aim (M)
Operator performance in controlling a virtual lunar rover during simulated lunar gravity
Findings
Operator performance improves with practice under simulated lunar gravity
Khudyakova (2021)
10.1063/5.0035989

Aim (M)
Reduce the physical cues of forward jumps in a gravity-reduced environment
Findings
Visual gains can extend the perceived jumping distance and height
Kang (2019)
10.1109/vr.2019.8798251

Aim (M)
Influence of visual information on running adaptation in a realistic Mars-like environment
Findings
Locomotor and perceptual adaptations were not similarly impacted by gravity / visual context
Keime (2023)
10.3389/fphys.2023.1201253

Aim (M)
How gravity alterations affect decision-making
Findings
Microgravity increased subjective confidence
Loued-Khenissi (2023)
10.1038/s41598-023-36775-0

Aim (I)
Investigate Mars extravehicular activity (EVA) concepts
Findings
New capabilities were moderately enhancing for future planetary EVA
Beaton (2020)
10.1016/j.pss.2020.105003

Aim (M)
How simulated Martian gravity and visual disorientation affect dynamic balance
Findings
Performance with visual-vestibular conflict was better in 0.38 G compared to 1 G
Rosenberg (2022)
10.3390/brainsci12101268

Aim (M)
Influence of microgravity on perspective-taking abilities
Findings
Microgravity selectively facilitates perspective-taking abilities requiring mental rotation in the frontal plane.
Meirhaeghe (2020)
10.1016/j.actaastro.2020.01.039

Aim (M)
Effects of color and simulated microgravity on cognitive task performance and emotion
Findings
0G significantly reduced task performance and positive emotions, while lunar gravity did not
Jiang (2023)
10.1016/j.buildenv.2022.109789

Aim (M)
Develop an underwater virtual reality system for neutral buoyancy training
Findings
VR system effectively trained participants in jetpack locomotion
Sinott (2019)
10.1145/3359996.3364272

Aim (I)
benefits of using AR for executing complex procedures in a NASA mission environment
Findings
AR instructions were beneficial for executing complex procedures
Nuernberger (2020)
10.1109/mcg.2019.2957631

Aim (M)
Efficacy of virtual reality as a countermeasure for astronaut motion sickness
Findings
Motion-congruent visual cues in VR may be effective in reducing moderate nausea
Lonner (2023)
10.1007/s00221-023-06715-5

Aim (M)
Is learning progress faster with 3D vs 2D in manual spacecraft docking training?
Findings
3D presentation resulted in slightly faster initial learning but no long-term performance advantages
Piechowski (2020)
10.1016/j.actaastro.2020.08.017

Aim (M)
Study visual exploratory activity in microgravity using VR
Findings
VR potentially reduces space motion sickness and aids vestibular adaptation in microgravity
Rojas Ferrer (2019)
10.1109/vr.2019.8798253

Aim (I)
Can artistic VR experiences enhance emotional and physical well-being in ICE conditions?
Findings
VR significantly reduced perceived stress-related symptoms and was well-received by participants
Pochwatko (2023)
10.1109/ismar59233.2023.00033

Aim (M)
Overview of European microgravity research and the various national and international programs
Findings
Microgravity research provides opportunities for advancements in science and industrial processes
Seibert (2001)
ISBN 92-9092-604-X

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