Title: *Design Recommendations for Interactive Mental Health Chatbots used in Space Missions: A Pilot Study*

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I led all stages of the research process, including designing and building an AI program, organizing participant testing, analyzing both qualitative and quantitative data, and drafting the final manuscript. Additionally, I managed partnerships with institutions, ensured compliance with research protocols, and incorporated feedback from advisors and participants to refine the program's features and methodology.

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- Rise Global Finalist
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Original Paper

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Abstract

Background: Communication problems that may arise in long-distance space travel missions, such as signal latency, limited bandwidth, and space radiation interference, can compromise continuous psychological monitoring. To address this issue, space agencies are exploring AI-based digital and robotic mental health solutions, including therapy, counseling, and psychological assessments. Two prominent examples include the European Space Agency's VR Mental Care project, which uses immersive environments to reduce stress, and CIMON, a robotic assistant on the International Space Station (ISS) that provides companionship to alleviate isolation.
Objective: We sought to examine initial reactions of space and space travel experts to a mental health chatbot.
Methods: We fine-tuned the Alpaca 7B large language model using several datasets of conversations between psychologists and patients in order to create empathetic and contextually appropriate responses. We call this chatbot LorelAI. We ran a preliminary pilot study with four members of the Republican Center for Space Communications of Kazakhstan and four former participants of long-duration (4 to 12 month) NASA Mars simulation missions, who were introduced to LorelAI in a remote study where they interacted with LorelAI independently. Our interview questions studied five aspects of the AI chatbot: response quality, visual design and usability, response length, AI voice quality (including customization, activation, and deactivation), and response speed.
Results: Several key needs related to the isolated nature of space travel were identified, including crew cohesion support, stress management, empathy, humor, contextual awareness, future-oriented conversations, task assistance, information access, breaking repetitive patterns, entertainment engagement, personalization, and visual stimulation. Additionally, all eight participants agreed that response quality must be improved, that responses should be provided in a conversational manner, and that the AI's voice must be customizable. However, preferences for visual design and response speed varied significantly.
Conclusions: This work provides initial qualitative evidence for design guidelines that should be considered when designing chatbots optimized for maintaining astronaut wellbeing, productivity, and mission success during long-range space missions.

Keywords: interactive mental health chatbots, space missions, AI-powered psychological support, customization of AI assistants, astronaut well-being, human-computer interaction (HCI), long-distance space exploration

Introduction

Space exploration is of current global interest, with a growing number of planned long-distance space exploration (LDSE) missions and significant resources being invested by governments worldwide [1], [2], [3], [4]. The psychosocial elements of human behavior and performance are critical to understand from a human factors' perspective. Research in this field is ongoing, constituting an entire branch of NASA's human research roadmap.

Currently, there is a trend of underreporting psychological issues among astronauts, which possibly fosters the perception that these problems are not as severe or prevalent as they are and lead to a misleadingly optimistic view of the mental health of space travelers. However, it remains uncertain whether this trend of underreporting will continue in future space missions, particularly as missions become longer in duration and more isolated from Earth. Moreover, the duration for a radio signal traversing between Mars and Earth varies from about 4 to 21 minutes, depending on the relative positions of the two planets; this means that real-time psychological monitoring by human experts will be very difficult to engineer [5].

In order to tackle this problem, NASA, ESA and similar space agencies are exploring robotization and digitalization of mental healthcare – that is, the integration of robotic and AI technologies within the space systems for providing psychological support in addition to performing operational tasks. One example is ESA's VR Mental Care project, which uses virtual reality to provide mental relaxation, improving astronauts' overall mental health [7]. By wearing a headset, crew members experience immersive 360-degree environments and provide feedback through questionnaires. Another example is CIMON—an AI-powered robot launched by SpaceX— which is equipped with microphones, cameras, and emotion-detecting software for missions to the International Space Station [7]. CIMON aims to protect astronauts from mental health risks associated with prolonged isolation and communication delays. Additionally, CIMON helps prevent groupthink—a phenomenon where isolated groups may make irrational decisions—by serving as an objective outsider[7].

There is abundant research in human-robot interaction (HRI) within medical facilities and other settings that explore the perception and effectiveness of mental health robots [8], [9], [10], [11], [12], [13], [14]. However, compared to environments such as medical facilities, care homes, and general applications, there is limited HRI prior research focused on the space exploration domain.

There are many aspects to consider when building a social robot for space settings. Prior work on mental health robots for space travel has indicated that the robot's design should offer simultaneous support for both individuals and groups onboard the spacecraft [15]; it must also operate independently, without reliance on other systems on the craft or real-time access to the Internet or deep space network.

We seek to expand upon prior literature by studying the application and customization of AI-powered mental health chatbots specifically designed for use during long-duration space missions, assessing their effectiveness in providing psychological support and evaluating user preferences for voice and response quality, response length, and visual design. We developed the LorelAI chatbot system, an AI-driven psychological support bot that we developed.   We evaluated the technology's effectiveness in assisting astronauts during long-duration space travel through interactive dialogue and identified areas for further development through a user study with participants with experience in the space industry or space mission simulations. We provide design recommendations for future iterations of space chatbots. Our study aimed to answer the following research questions:

RQ1: How do communication affordances, such as response time, voice quality, and design factors, influence user perception and engagement in space-related contexts?
RQ2: What design improvements and implementation strategies are necessary for AI-powered mental health support technology to be effective in future space missions?

RELATED WORK

The primary purpose of "social robots" is to foster social interactions rather than simply completing tasks. One family of thought is that a social robot must have a physical embodiment [16], while others [17] include telepresence (screen) robots as a subcategory of social robots [18]. The importance of robots' physical presence [8], [19] was explored along with their other features such as the ability to support a conversation and the utilization of social cues such as body movements, facial expressions, gestures, and even synchronization [20]. Naneva et al. consider robots' ability to be perceived as a social entity to be a distinct feature [21]. When generally studying people's trust of and interest in social robots, it has been shown that even subtle aspects, such as the initial unboxing experience [22], can have a major effect on users' enthusiasm and trust towards the devices. Interestingly, in domestic settings, social robots intended for independent living assistance were primarily perceived as entertainment devices, potentially due to the good health of study participants [23].

Social robots have been increasingly used in mental healthcare facilities and similar settings such as care homes [24], where social assistance is needed for the improvement of patients' quality of life. There is a trend towards introducing both humanoid and zoomorphic social robots to patients with dementia [25], [26], [27], [28], [29], [30]; specific conversational strategies have been shown to increase user engagement among dementia patients [31], [32]. However, while social robots are a promising means of increasing the effectiveness of dementia therapy, the risks of such interactions must be taken into consideration. First, safety concerns arise from inaccuracies in personalization. Second, there is the risk of infringing on human autonomy, as over-reliance on these systems could diminish independent decision-making. Third, robots designed to substitute human interaction could exacerbate social isolation. Lastly, manipulative design practices, often referred to as "dark patterns," pose a risk of exploiting users for unintended purposes [33]. Also, while a social robot can be useful in such settings, there is often a need for a moderating person [34]. So, social robots, regardless of their form, have tended to affect users in mental healthcare facilities mostly positively, but they must continue to be developed with respect to ethical and safety concerns.

When designing a social robot specifically for mental health support during LDSE missions, it is essential to consider the details of LDSE missions and related psychosocial issues. While we know that space travel leaves an overall positive impression on astronauts and cosmonauts [35], the prolonged social isolation it entails poses a significant challenge. There is abundant research on psychosocial issues that affect mission success during LDSE missions, from both an individual and interpersonal standpoint [36], [37], [38], [39]. Moreover, even though astronauts are currently able to receive extensive psychological support like private counseling sessions and access to exercise and leisure activities, maintaining such services may become significantly less feasible due to time delays in communication and limited bandwidth as the distance between the spaceship and Earth increases. Future missions might require adaptations like telemedicine advancements or AI-powered support systems to address these challenges. Experimental studies conducted in the HI-SEAS habitat have looked at the effectiveness of digital solutions in such situations. For instance, Lyons et al. investigated the performance of two self-directed interventions: Expedition-APPP, a digital platform offering interactive tools for conflict resolution, stress management, and depression treatment, and immersive nature VR experiences [40]. They found that Expedition-APPP fostered a shared sense of community and provided effective coping mechanisms, while VR facilitated access to positive emotions and experiences unavailable within the habitat. In yet another study conducted at HI-SEAS, Anderson et al. investigated the impact of a suite of interactive digital psychological programs. The results suggested that these interventions played a significant role in supporting behavioral health [41]. Overall, the evolving understanding of the factors affecting crew well-being during LDSE missions, combined with the ongoing testing of technologies and interventions, reflects a commitment to enhancing the mental health of space travelers in the face of challenges posed by LDSE.

Building upon these foundational prior works, our study seeks to address two key areas of psychological challenges identified by Manzey (2018) as crucial for Mars missions: (1) individual adaptation and performance and (2) the conceptualization and implementation of psychological countermeasures. While extensive research exists in both AI for social settings and psychological interventions for LDSE, a significant gap remains in the development of AI-powered robotic solutions specifically designed for LDSE conditions.

Methods

This study was approved by the University of Hawaii Institutional Review Board (IRB) under protocol number 2023-00760. The primary objective of this study was to assess the effectiveness of a digital software program, LorelAI, through a comprehensive evaluation of its usability and acceptability, including response quality, response length, visual design and usability, voice quality, activation and deactivation, and response speed.

Chatbot Development

We developed a web system to host the LorelAI chatbot (Figure 1). We built LorelAI by fine-tuning theAlpaca 7B model [43] a publicly available instruction answering model fine-tuned on Llama-2-7B [42]. For our fine-tuning of Alpaca, we used a multitude of publicly available datasets [44], [45], [46], [47] consisting of conversations between psychologists and patients. This training enables LorelAI to simulate empathetic and contextually appropriate interactions, making it suitable for providing mental health support in isolated and challenging environments such as space missions.

Web System

The program operates through a website interface (Figure 1) featuring an input window labeled "*You said,*" and an output window labeled "*Answer*". Users begin their interaction by clicking the "Start" button to initiate speech input and the "Stop" button to conclude their speech, sending the input for processing. The AI then generates a response, which is displayed in the "Answer" window. Additionally, users can listen to the AI's response by clicking a gray play button. A response from LorelAI typically ranges between 150 to 170 words, adapting to the nature of the response — e.g. whether it is a greeting (10-30 words) or a piece of advice (120+ words). LorelAI's functionality is optimized for both reading and auditory engagement, making it versatile for different user needs and scenarios.

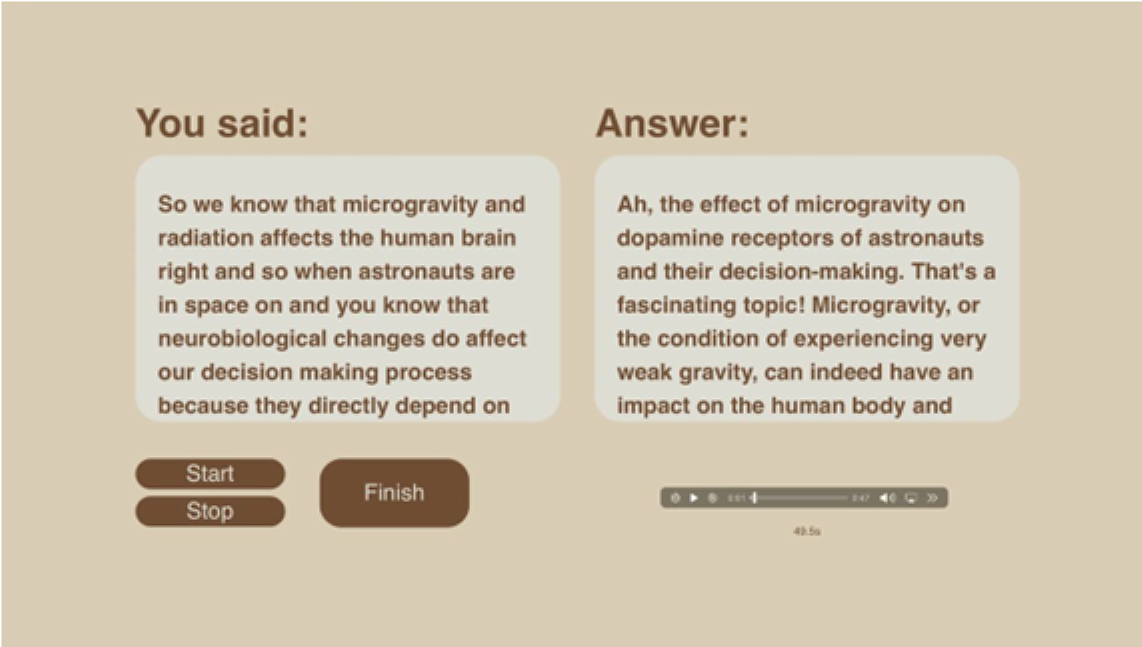

Figure 1. User interface of the LorelAI program. Participants speak to the chatbot, and their text is displayed on the screen. LorelAI then generates a response that is provided as text on the screen and corresponding audio.

Recruitment

Eight domain experts were recruited for the study. Participants 1-4 are experts in the space industry from the Republican Center for Space Communications (RCSCK) of Kazakhstan, without direct experience in social isolation, whereas Participants 5-8 are former HI-SEAS (Hawai'i Space Exploration Analog and Simulation) program participants who have directly experienced long-term social isolation as part of the program. HI-SEAS is a research program situated on Mauna Loa in Hawaii, designed to simulate the conditions of Mars and lunar missions. The program aims to study the psychological, social, and operational challenges associated with long-duration space travel [48], [49]. Missions at HI-SEAS typically range from four months to a full year, providing comprehensive data on crew dynamics, stress management, and the overall impact of prolonged isolation and confinement on human performance.

Procedures

Due to geographical constraints, the study was conducted remotely. We introduced participants to the LorelAI program via a 10-minute Zoom conference, after which they independently interacted with the program. The task included a 30–60-minute conversation with the digital software in which we instructed participants to enact a scenario where they experienced emotional distress or similar conditions during space-related work. The subjects were required to interact with the program from a quiet environment to minimize distractions and maximize focus on the interaction.

After the interaction, we asked all 8 participants to respond to the questions listed in Table 1, either in written or audio form. The questions listed under *Part 1: General Digital Platform Evaluation* were asked to all 8 participants, while questions listed under *Part 2: Space Exploration-Specific Inquiry* were directed exclusively to the 4 HI-SEAS participants, focusing on matters specifically related to space exploration.

Table 1. Interview questions

№	**Part 1: General Digital Platform Evaluation**	**Part 2: Space Exploration-Specific Inquiry**
1	*How did you find the user interface and overall software design of the digital platform?*	*How should a chatbot help you cope with loneliness and isolation during a space mission? What features or strategies would be most helpful?*
2	*Did the voice and speech patterns of the digital assistant appear natural and engaging to you? Please elaborate.*	*Space missions often involve long periods of repetitive tasks and limited stimulation. What personalized features should the chatbot include to help break the monotony and keep you mentally engaged during these periods?*
3	*Were there any specific features of the digital platform that stood out positively or negatively during your interactions?*	*The confined space of a spacecraft can be psychologically challenging. What features should the chatbot offer to help you manage feelings of claustrophobia or cabin fever?*
4	*How would you rate the software and features of the digital platform, taking into account the ease of use and its ability to engage you, on a scale from 1 (very poor) to 10 (excellent)? Please explain your rating and highlight any particular features that influenced your assessment.*	*What aspects of long-term space travel do you find most burdensome on mental health?*
5	*How do you envision the integration of this digital platform into space exploration and psychological research in the coming years, considering your personal background and experience with this technology? How successful do you think this technology can be?*	*How might a chatbot be able to help alleviate these challenges?*

6	*What do you think can be improved?*	

Qualitative Analysis

We conducted a thematic analysis of all interview responses. All authors derived emerging themes after analyzing the raw interview responses. Afterwards, the first two authors independently reviewed each quote and mapped the quotes to themes. Any disagreement was discussed, and if a consensus was not reached, then the last author broke ties.

Results

Part 1: General digital platform evaluation

Table 2. Raw responses to the general digital platform evaluation questions.

Theme	**Answer example**

Response quality	**Insightful/Satisfactory:** - *"Strives to be helpful and asks appropriate questions."* - *"It responds quite reasonably to sensible questions and avoids nonsense."* - *"The program provided thoughtful answers that made me think and guided the conversation in unexpected directions."* - *"After a few questions and responses, the digital assistant appeared more natural and engaging, compared to its appearance during the first several questions."* - *"The advice is useful and related to the question being asked."* - *"I noted positive features such as the availability of information, a wide range of functions, and opportunities for learning and research in the field of psychology."* **Generic/Unsatisfactory:** - *"Missed my intentions on many occasions."* - *"The empathy of the AI could be improved."* - *"Most of the advice given was things I already knew."* - *"It often threw my own statements back at me, but said differently, which came across as 'mansplaining.'"* - *"I didn't feel enough actual support. It sounded more like 'work' because it kept asking questions that couldn't be answered with a simple yes or no."* - *"Too generic."* **Development:** - *"A psychological assistant should consider the tone and irritability of a person."* - *"There are a lot of sentences in the responses, which could be improved by cutting down to the main topics that the user is interested in. This would be especially useful and helpful if a person is in a hurry, agitated, and doesn’t have time to read a whole paragraph of responses or listen through the entire reading."* - *“Socrates asks questions that lead the listener to the thought he wants to convey, just like artificial intelligence should.”*

Visual design and usability	**Easy to use/Satisfactory:** - *"Overall, the program had an easy-to-use and uncomplicated interface."* - *"The platform was pretty good at converting what I said into text. This needs further development."* - *"I appreciate the minimalism, but this is too minimal. Adding a few icons or short sentences like 'Ask a question or send a reply' could help users figure things out more quickly."* - *"I like the fact that it shows the time it is generating a reply."* - *"Pleasant visual impression, attractive and intuitive."* - *"Simple, easy to operate, and quick to get used to."* - *"During moments of extreme irritation, it does not create additional triggers of irritation."* - *"Simple to understand and well-integrated."* **Primitive/Unsatisfactory:** - *"In my opinion, the design is primitive and does not help improve mood."* **Developments:** - *"The 'Answer' response window should be longer/bigger, so that there is less scrolling and more text immediately visible."* - *"The font size of the reply is too big. Making it smaller would make it easier to capture the overview."* - *"When you press the request button, it would be beneficial to have a clear indication like in WhatsApp."*
Response length	**Too long:** - *"Instead of preparing a long answer and asking questions, it would be nice if it processed requests by sentence and provided feedback, asking questions one after another."* - *"The answers were sometimes too long to read, especially when I had to keep scrolling down."* - *"While I appreciated the follow-up questions to guide the conversation, I felt the need to break the conversation myself, which seemed a little jarring."*

AI voice quality, customization, activation, and deactivation	**Engaging/Satisfactory:** - *"The voice and speech of the digital assistant sound natural and appealing."* - *"Considering modern achievements in mimicking human voice, very good."* **Robotic/Unsatisfactory:** - *"Currently, Lorelai seems somewhat robotic, lacking naturalness."* - *"It was clearly a computer voice."* - *"It is obvious that it's mechanical, naturally sourced from somewhere."* **Developments:** <u>Selection of Voices</u> - *"I would like perhaps a choice of the assistant's voice."* - *"If you could choose different voices, maybe even the voices of famous people, globally known people, it would enhance the feeling that there are more people to talk to when you are in isolation for a long time."* - *"To make it more natural, the key might be intonation, allowing emphasis on specific words or phrases, training AI to recognize these nuances."* - *"Analyzing speech patterns would enable AI to become more natural."* - *"A possibility to choose a specific voice could be nice."* <u>Activation/Deactivation</u> - *"In the future, it would be more natural to have voice activation and deactivation of functions so that the AI is in listening mode from the start."* - *"Finally, I think that once the response is created, the software should immediately start speaking, which will make it more realistic in terms of live assistant."*

A total of eight participants participated in the study: four from RCSC and four from HI-SEAS (Table 2).

A notable difference in perception emerged regarding the AI program's response quality across groups. The HI-SEAS group's negative feedback was more pronounced, with comments like "*too generic*" (Participant 5) and *"didn't feel like actual support*" (Participant 6). This may reflect the HI-SEAS participants' experience and deeper understanding of long-term mission challenges, suggesting a need for more studies in specific environments like simulated Mars missions or real ISS missions.

Six out of eight participants found the program's design satisfactory and easy to use, but most agreed it needed further simplification. They suggested reducing the number of buttons to one or eliminating them entirely, favoring voice control for easier use in confined spaces. Participants also recommended improvements to the voice feature: adding a way to restart recordings, including an audio cue when responses are ready, and simplifying the process for discarding recordings. Participant 5 mentioned they would prefer typing if automatic voice detection was not available. Two participants critiqued the design as "*primitive*," suggesting the addition of icons or short text for easier navigation. Three participants expressed a desire for a visualized face for the assistant, with one saying, "*it is necessary to add a visualized face of the assistant with adjustable settings for each user*." These differences highlight the need for personalized psychological assistants.

All 8 participants reached a consensus on the length of answers and the quality and customization of the AI voice. Those who commented unanimously agreed on several key points regarding the design of responses:

- The answers should not be too long.
- Questions should be asked one-by-one.
- The AI should have memory, allowing it to refer to information received from the user and previous dialogues.

All participants agreed that users should be able to customize the AI voice, with some suggesting options like famous people, relatives, children, or cartoon characters. However, Participant 1 offered a unique perspective, stating that a voice too similar to a real human's would reduce their trust in the program due to the uncanny valley effect, where overly realistic features cause discomfort. This highlights the need for developers to consider diverse and unexpected preferences when designing the AI's voice options.

We will now focus on the fifth question because it highlights key aspects of the technology's potential and practical impact: "*How do you envision the integration of this digital platform into space exploration and psychological research in the coming years, considering your personal background and experience with this technology? How successful do you think this technology can be?*" Several themes emerged from the interviews:

1. Timeline for implementation
2. Necessity of a psychological assistant

3. Technical integration details
4. Personal sentiments

Regarding the timeline for implementation, Participant 1 argued that "*the integration of this technology is not a near-future concern*" suggesting it may not be necessary for shorter missions. Participant 5 shared a similar view, noting that "*this is only potentially beneficial for long-term stays in space*."

Participant 5 emphasized the challenges of using AI for psychological support. They noted that "*getting AI to provide psychological support is always going to be a challenge*" and claimed that "*given the complexity of human emotions, this is probably the most difficult use case for AI."* Despite these challenges, Participant 5 emphasized the genuine need for such technology, stating that "*the need is real. People in isolation could always use better support tools*." Participant 3 affirmed the necessity of the technology, stating, "*I think this is a very necessary thing. Yes, when you are in isolation, it's interesting to talk to someone*." Moreover, Participant 8 added that "*Although every crew member is different, with different personalities, this type of psychological tool can be useful to some of the crew members and should be included as part of the mission*." Participant 6 suggested it could be useful as a general reference, providing astronauts with easy access to advice and strategies for general issues, rather than specific or personal problems, in an engaging way. They noted that this would complement psychological care rather than replace it.

Concerning the technical aspects of implementation, Participant 1 envisioned this technology as part of a universal medical monitoring system for Mars missions, which they referred to as the "Crew Well-Being Management System", which would monitor various health metrics such as sugar levels, hormones, neurotransmitters, and air quality. They also noted that, "*It is important to conduct not only subjective assessments of the team members' emotional states but also objective studies*." They proposed that each crew member should report daily on their feelings and interactions, allowing the system to detect unusual patterns. The system could then ask leading questions to help identify issues, such as, "*Were you a bit upset today when you talked with [name of crewmate]?"* Also, rather than providing direct recommendations to the crew member, Participant 1 suggested that the system would propose actions to the ship's captain: "*If something is wrong, the system will not provide direct recommendations to the crew member but will suggest resting*". For example, the system might advise the captain to recommend a crew member to take a break or avoid extravehicular activities if their condition requires it, ensuring the well-being of the crew without direct intervention from the system itself. Participant 7 added that everyone could have their own personal chat assistant, which they could consult on a laptop or mobile device. Finally, regarding the operation of the program, Participant 1 posited that a Deep Space Network of satellites between Mars and Earth is necessary for data transmission. However, this system would incur a communication delay of up to 50 minutes for a return answer, which is suboptimal. Hence, they concluded that it is crucial to have the AI core on the spacecraft itself to mitigate this delay.

Personal sentiments reflected open-mindedness and suggestions for enhancements to maximize utility. Participant 2 conveyed optimism about its future integration into space exploration and psychological research, stating, "*the integration of this digital platform in space exploration and psychological research in the coming years seems promising*." They further suggested, "*this technology could become an important tool for research and training in these areas*." They believed the platform has the potential to significantly advance space exploration and psychological support. Participant 8 agreed, stating, "*I can see this being integrated in future space missions*." Participant 7 added that with improvements in its voice and technology—making it more natural, empathetic, and humorous—"*people in (simulated) space will really love it*."

Part 2: Space exploration-specific inquiry

This section focuses on questions specific to space-related challenges, posed only to the four HI-SEAS participants. The primary themes identified in the participants' answers are displayed in Table 3.

Table 3. Responses to space exploration-specific questions from HI-SEAS participants.

Theme	Quote
Crew cohesion support	• "*Help to figure out/resolve crew tensions*." – Participant 7 (Q5) • "*A chatbot would be very helpful if designed with some crew input in mind*." – Participant 8 (Q4)
Stress management assistance	• "*Might be helpful in providing coaching or resources to aid in personal stress management."* – Participant 6 (Q1) • *"Lack of information and the limited opportunities to communicate with friends and family outside of our simulation were the most burdensome aspects on mental health."* – Participant 5 (Q4)
Empathy	• "*Showing 'genuine' empathy and truly following up on answers*." – Participant 7 (Q1)

Humor	• *"Humor is definitely very helpful, with some irony and occasionally putting itself into perspective."* – Participant 7 (Q1)
Contextual awareness and flexibility	• *"Important that it doesn't overdo [questions], and senses when you don't need this kind of conversation."* – Participant 7 (Q1) • *"A chatbot could greet crewmembers each morning (once turned on) and ask them if they want to talk or be left alone."* – Participant 8 (Q1)
Future oriented conversations	• *"Talk about plans, about what you want to do after the mission. This reminds participants that they have way more ownership over their time/plans/life than the current situation."* – Participant 7 (Q3)
Task assistance and access to information	• *"Ask about the tasks and discuss them and offer help/suggestions when needed."* – Participant 7 (Q2) • *"A tool that could collect and synthesize relevant information quickly to eliminate multiple message exchanges would improve our information access. If I ask how to fix something, I really need the ground support to answer that question but also be a few steps ahead to provide answers to the obvious follow-up questions as well."* – Participant 5 (Q5)
Breaking repetitive patterns	• *"I found with the frequent surveys that we had to fill out during the mission, it'd be easy to almost fall into an automatic mode...Something that might help is to add some variation, something to break up the repeated nature of the interactions and encourage the user to actually evaluate what the chatbot is prompting during a given session."* – Participant 6 (Q2)
Engagement through entertainment	• *"A chatbot could also have a daily feature, such as a joke of the day, talk about weather back on Earth (any city chosen by a given crewmember), top headline news, or something of interest to crew in isolation."* – Participant 8 (Q1) • *"A chatbot could remind the crew of all different ideas of how to pass time."* – Participant 8 (Q3) • *"Trying to figure out what you're interested in and then daily offer you nuggets of information. Like 'Hey, by the way, did you know that in this year, this and this happened?'"* – Participant 7 (Q2)

	• "*A chatbot could also have a daily trivia or a question that is posed to the crewmember*." – Participant 8 (Q2)
Visual stimulation	• "*Open-world video games like Minecraft and Flight Simulator gave me virtual high-quality 'worlds' to explore that helped me feel less confined and isolated during my year at HI-SEAS*." – Participant 6 (Q3) • "*Perhaps a chatbot can have a daily short video of nature, such as flying through mountains, over the ocean, or near some beautiful and vast natural area. This would give the crew a feeling of big spaces, large distances, and reduce the feeling of claustrophobia*." – Participant 8 (Q3)

Two participants expressed skepticism about a chatbot's ability to address loneliness and isolation, stressing that it cannot replace human interaction. However, Participant 6 noted that it could provide helpful resources for managing these challenges. Others suggested the chatbot could: (i) show empathy and follow up on conversations, (ii) be context-aware to avoid over-engagement, (iii) use humor to lighten interactions, (iv) greet crew with the option to engage or be left alone, (v) offer daily features like jokes or news, and (vi) allow customizable voices for a more personal experience.

When asked how a chatbot could help with monotony, participants suggested: (i) adding variety to interactions to avoid automatic responses during tasks like surveys, (ii) asking about daily tasks and offering help when needed, (iii) providing personalized information like trivia or historical facts, (iv) using colorful displays to create a stimulating environment. However, Participant 5 noted that their main challenge was not monotony but the lack of timely information due to delays, suggesting that an information-gathering tool would improve life on Mars.

When asked about the most burdensome aspect of spaceflight, one half of the participants highlighted the isolation from family and friends, while the other half emphasized the complexities of crew interactions, which included (i) maintaining crew unity, (ii) balancing the need for a community-oriented spirit with the need for autonomy and privacy, and (iii) maintaining good relationships with mission control.

The final question on the general usefulness of chatbots in addressing participants' challenges revealed two distinct views. The first subgroup (Participants 7 and 8) viewed the chatbot as an emotional support tool, suggesting that it could (i) help resolve crew tensions and (ii) act as a companion available day or night. The second subgroup (Participants 5 and 6) took a more technical perspective, seeing the chatbot as a "*smart* *search engine*" (Participant 6) and "*a tool to collect and organize information*" (Participant 5).

Discussion

Comparison to Prior Work

We evaluate our findings against prior work studying mental health technologies for space travelers. In particular, we compare our results to former HI-SEAS studies evaluating mental health considerations in long-range space missions. In 2016, Anderson et al. evaluated the Virtual Space Station (VSS), an interactive platform for psychological training and treatment, and found it to be a valuable resource for facilitating stress management, providing unique support for conflict resolution, and addressing the diverse psychological needs of crewmates. Engler et al. introduced robotic companions to reduce stress and nurture emotional connections among crew members by providing them with both passive and aggressive robot models over a three-day period, finding that while the robots had a positive impact, their actions were too simple and repetitive, requiring more affective complexity for stronger emotional connections. In 2023, Anderson et al. evaluated the use of immersive virtual reality (VR) based on attention restoration therapy, finding that responses varied, with some participants finding nature-based VR restorative, while others preferred more dynamic, familiar environments after isolation. This highlighted the importance of tailoring psychological support in isolated, confined, and extreme environments. Lyons et al. explored the Expedition Application for Peak Psychological Performance (Expedition-APPP), which featured tools for managing stress, conflict, and depression, alongside nature-based VR scenes aimed at improving focus and reducing stress. They found that VR enabled access to emotions and experiences unavailable in the habitat; however, participants expressed a desire for a wider range of content to accommodate different coping styles.

In contrast to these prior works, we studied a mental health chatbot using LLM technology. Below, we compare and contrast the findings from our user study against the prior HCI studies investigating chatbots as well as studies focused on mental health technologies for space travel.

Principal Results

Based on our findings, we have formulated a list of design considerations for mental health chatbots deployed in long-range space missions. We discuss our guidelines in the context of the prior HI-SEAS studies described above.

The system should prioritize creating a psychologically supportive environment. This can be accomplished by adapting to the emotional states of crewmates, remembering past interactions to build continuity, and fostering a sense of autonomy. Four participants highlighted the need for the system to recognize emotional states, such as irritability or calmness, and respond appropriately, showing genuine empathy and interest without becoming intrusive. Additionally, participants expressed frustration when the system forgot previous conversations. A sense of autonomy can be fostered through future-oriented discussions such as post-mission plans. One participant noted that these conversations helped them feel a stronger sense of control over their time and life, despite the confined environment. Interestingly, the theme of control also appears throughout several prior socially assistive programs, whether it involves gaining control over participants' emotions [40] or stress [41]. This is understandable, as in confined environments, individuals may feel a loss of control over many aspects of their lives due to strict schedules, isolation, limited autonomy, and emergencies. Therefore, socially assistive programs should create a sense of choice and freedom in participants' daily lives, along with being human-like and flexible.

The system should provide concise responses, delivering focused answers and avoiding unnecessary details that might overwhelm the user. Participants also suggested that the chatbot should offer layered information, providing additional details only upon user request and posing follow-up questions one at a time. Study participants also recommended that human-like interactions be mimicked by incorporating natural speech patterns into conversations ,including interactive placeholders such as "Let me think" or "Processing your request" during longer processing times in order to keep the user engaged. Appropriate humor usage was also suggested to lighten the mood and help users cope with the stress that can be encountered in long-range space missions. These findings align with the 2016 study by Anderson et al., where participants expressed a desire for an educational module used in that study to be interactive rather than solely content based [41]. **The system's entertainment program should be enriched with daily content such as jokes, trivia, Earth weather updates, and news headlines to keep astronauts engaged**. Two participants expressed interest in receiving personalized content tailored to their individual preferences. Additionally, one participant suggested that the system should recommend activities to remind astronauts of various ways to pass the time and prevent boredom during long missions. Virtual experiences, such as short videos or virtual reality experiences of nature and expansive environments, should also be offered to help alleviate feelings of claustrophobia. The desire for more video-based materials aligns with findings from another HI-SEAS study [41], where users also expressed a preference for videos. While in our case, the suggestion for more videos stemmed from users wanting to feel more connected to life on Earth, in the Anderson et al. study, the suggestion was aimed at making conflict resolution learning more accessible and engaging. In another study, VR solutions have proven successful in improving social connectedness. Ultimately, incorporating visuals into socially assistive programs can meet multiple user needs, such as regaining a sense of normalcy, providing entertainment, and fostering social relationships. The differing perceived utility value of a natural scene virtual reality solution was also evaluated in another HI-SEAS study [57]— while many found it restorative, others preferred dynamic and familiar scenes with people, indicating that psychological support tools like VR need to be individualized for different users and settings. A visualized face for the assistant is also a possibility suggested by one participant in our study. While we learned that visual solutions are valuable, this does not mean that socially assistive programs must be primarily visually based. In a previous study on self-directed conflict resolution tools, such as the Expedition-APPP and VR nature scenes [40], participants sought a broader range of content to accommodate different coping styles. This suggests that instead of offering a large amount of one type of content, a balanced variety is necessary to meet diverse needs. This was evident in our study, where some users preferred texting while others favored talking, reflecting their varying preferences.

The interface should be simplified with minimal buttons and controls. Voice control should be prioritized for hands-free use in the challenging settings that can occur in long-range space missions. Clear visual indicators should guide user actions, ensuring intuitive interactions. Participants also suggested incorporating a continuous listening mode with "always on" capabilities to avoid manual activation. These suggestions are similar to those from Anderson et al.'s 2016 study [41], where participants expressed a desire for a more intuitive interface of the Virtual Space Station platform. However, while the interface should be simplified, elements that enhance interaction—such as knowledge, emotional awareness, communication style, and entertainment—should instead be highly enriched [50]. Engler et al. showed that low engagement stems from a lack of complexity in emotional interactions [51].

Given the varied user responses regarding the design and differing personal needs, the system should offer both visual and voice customization. Some users found LorelAI “easy to use” and “attractive,” while others felt it was “too minimal.” To address these differences, users should have the option to adjust colors, font sizes, and layouts according to their preferences. This aligns with previous studies [52], [53] on the customization of various types of user interfaces, highlighting that customizable features are generally important to foster user acceptance. Additionally, users should have the ability to customize the chatbot's voice, including adjustments to tone, pitch, and speed and mood. Three out of eight participants expressed a desire to choose a voice resembling a famous person, a family member, or a favorite TV character. These findings echo previous studies on the customization of voice assistants [54], [55], [56],which showed that voice customization increases trust and can even persuade users to take certain actions. In our study, although personal preferences were examined, gender preferences were not analyzed due to the homogeneous sample consisting entirely of male participants. In the 2016 study of Anderson et al. [41], however, participants noted that gender differences should be also incorporated into the program.

Limitations

A primary limitation of this study is the small sample size, which was primarily an artefact of the specialized study population and the resulting difficulty in contacting relevant participants. Another significant limitation is the lack of gender diversity in the sample, as the study included only male participants, which is likely a reflection of issues of underrepresentation of non-males in the broader study population. This omission prevented the analysis of potential gender-based differences in preferences and experiences, which could have provided valuable insights. Additionally, the LorelAI testing program employed in this research may not be the most advanced or comprehensive chatbot available, potentially limiting the applicability of the findings. We note, however, that most chatbot-related research papers are likely to face this limitation due to the rapidly advancing nature of this field. Finally, as our study heavily relied on qualitative data, the interpretation of user trust, perception, and satisfaction can be subjective, with personal biases potentially influencing or skewing the interpretation, particularly given the small sample size. These limitations should be considered when interpreting the findings and considering their generalizability.

Future work

While overall feedback showed minor inter-group differences, negative responses were more pronounced among the HI-SEAS group, which can be attributed to their first-hand experience and understanding of the specific challenges astronauts face on long-term missions. This discrepancy highlights the necessity for further research in more specialized settings, such as extended simulated Mars missions or real ISS missions, to gain a more complete understanding of chatbot effectiveness in such environments. Additionally, it is essential to explore the long-term impacts of customizing AI to individual preferences during prolonged space missions. It would likely be fruitful to investigate the integration of more advanced technologies and improved natural language processing capabilities on user trust, perception, and satisfaction, as an outlier in this study has indicated a negative impact from highly natural-sounding digital assistants. By addressing these areas, future work can provide a deeper understanding of how to optimize AI-driven psychological support systems for space exploration.

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Conflicts of Interest

None declared.

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