Autonomous Psychological Support for Isolation and Confinement

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INTRODUCTION: Isolated and confined environments (ICEs), such as spaceflight, are challenging psychologically. We have been evaluating self-directed tools to sustain and improve psychological well-being in these settings. The Expedition Application for Peak Psychological Performance (Expedition-APPP) is an interactive media-based set of self-directed tools that address conflict resolution, stress management, and depression treatment. Virtual reality (VR) of nature scenes is a tool to improve attention and relieve stress by providing users with an immersive nature experience. We evaluated both Expedition-APPP and VR in an ICE.

METHODS: The Expedition-APP was evaluated during three, and nature VR during two, deployments at the HI-SEAS habitat, where crews of six were isolated for 8–12 mo. Participants used both the Expedition-APPP and VR and shared their feedback and experiences after the deployments in semistructured interviews. These interviews were evaluated using qualitative analysis techniques to gather generalizable insights into implementing autonomous mental health programs for people living and working in ICEs.

RESULTS: Expedition-APPP modules provided a shared culture, language, and tools for working through challenges. VR allowed for access to emotions and experiences that were unavailable in the habitat. Suggestions for improvement included making refresher training easily available and providing a wider range of content to address different individuals' coping styles.

DISCUSSION: Both the Expedition-APPP and VR were appreciated and used, although a wider range of content and experiences was desired by participants.

KEYWORDS: qualitative research, depression, virtual reality, mental health.

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As a group, astronauts function at a high level and are relatively free of psychological or psychiatric problems, but long-duration spaceflight can test any individual's psychological well-being.[6] Confinement, under- or over-work, sleep loss, and monotony can combine to worsen interpersonal tensions, produce stress, or even lead to depression. In the past, a variety of psychological events have occurred in both space and Antarctica, and these events have had a major impact on the missions.[6,15]

In addition to being carefully selected, crewmembers must psychologically prepare for a long-duration mission and then be able to recognize the signs of psychological problems both in themselves and in others during the mission.[17] They need tools to manage conflicts and to repair relationships after a dispute.[19] They need to be able to recognize and treat depression, anxiety, and other clinical problems. Technology-based approaches are appealing for psychosocial training and treatment in space because they can be used autonomously and confidentially.[7]

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Technology-based approaches to optimizing psychological well-being are particularly important and needed for long-duration spaceflights such as travel to Mars where early return or real-time assistance are unattainable. While missions to Mars may not be imminent, there are other isolated and confined environments (ICE) where these barriers to traditional, real-time or face-to-face psychological support also exist, e.g., Antarctic research stations.

Expedition-APPP (Expedition Application for Peak Psychological Performance) is a suite of web- or computer-delivered psychological training and treatment programs designed for use by astronauts on long-duration spaceflights to provide autonomous and confidential training and treatment (an earlier version was called the Virtual Space Station[7]). Expedition-APPP contains material on conflict resolution/prevention,[9] stress management,[22] and depression treatment.[8] Expedition-APPP uses the Virtual Practicum instructional design model developed at Dartmouth by Dr. Joseph Henderson,[14] which was adapted for psychosocial training with funding from the National Space Biomedical Research Institute. This Virtual Practicum model involves creating a game-like, computer-based environment that serves as a portal to various types of learning experiences. The goal of the model is not only to teach information, but also to build skills via provision of a simulation that mimics an actual interaction.

The Expedition-APPP was deployed to an isolated and confined environment (ICE) in an iterative set of three pilot studies. In two of the pilot studies, a nature scenes virtual reality (VR) system was provided along with Expedition-APPP because of the potential to reduce stress, improve mood, lessen fatigue, and renew productivity via immersive experiences with nature.[4] Some of the quantitative results from the pilot studies have been published elsewhere.[1,25] The full quantitative results regarding acceptability are available as supplemental data online (**Tables A, B, and C**, https://doi.org/10.3357/AMHP.5705sd.2020). After each wave of pilot testing, participants also engaged in semistructured interviews to elicit detailed feedback about the program modules. In this analysis, we explored these qualitative data from the semistructured interviews to identify generalizable insights into factors that could influence the implementation of virtual mental health programs for people living and working in an ICE.

METHODS

Design and Research Questions

Three single arm pilot studies included a postcompletion semistructured interview to elicit participant perceptions of the Expedition-APPP and VR programs. The studies were approved in advance by the Committee for the Protection of Human Subjects of Dartmouth College, the NASA Institutional Review Board, and the University of Hawaii Institutional Review Board. All participants provided written consent before participating. Sandelowski's[23] approach to qualitative description was used to answer the following research questions: What functions could the autonomous, computer-based mental health programs serve in isolated or confined environments? What barriers to their use would need to be considered before dissemination and implementation?

Subjects Setting and Participants

The Hawaii-Space Exploration Analog and Simulation (HI-SEAS) habitat served as a research setting to study the challenges of isolated living involved in exploratory planetary missions (specifically, Mars). The habitat is a 135.8 m^2 dome on the slope of Mauna Loa on the big island of Hawaii. Participants only left the dome of the habitat to perform simulated extravehicular activities (EVA) and wore a mock EVA suit at all times when outside. To simulate transmission delays that would occur on Mars, a 20-min time delay each way was imposed on all communication with people outside of the HI-SEAS habitat. Habitat maintenance and repair activities focused on the life support systems, such as the water and power systems, to provide the team with astronaut-relevant tasks within their environment.

Each cohort consisted of six crewmembers who were confined to the habitat for 8–12 mo depending on the mission. This study was conducted within the broader context of the HI-SEAS research study, where all crewmembers were chosen to fill the HI-SEAS research needs required for their respective missions. Crew selection focused on individuals displaying qualities generally found in astronaut candidates. To be selected, the individuals needed to have had an undergraduate degree in engineering or science as well as either 3 yr of experience or completion/enrollment in graduate education. Many of the crewmembers had no prior experience working with the National Aeronautics and Space Administration. Their professions included astrobiology, computer science, architecture, and engineering.

The pilot studies were pragmatic and opportunistic in that they were deployed within the larger research program of the HI-SEAS habitat. The Expedition APPP and VR development team played no role in selecting the crewmembers who would live at HI-SEAS nor did they design or administer any pretraining psychological evaluations or programming. The convenience sample of crewmembers were provided for the Expedition APPP and VR pilot tests only after their selection for the mission at HI-SEAS.

Equipment and Materials

The mood management module is a six-session, interactive media-based depression treatment program based on Problem-Solving Treatment, which is an evidence-based, cognitive behavioral therapy (CBT) for depression.[13] Through videotaped content, a psychologist guides users through the sessions. The program simulates the experience of interacting with a real therapist through extensive video and audio content that is tailored to the responses of the participant. The program tracks the user's depression symptoms at each session and guides users through the CBT process, troubleshooting any difficulties with problem solving through the use of failure analysis algorithms.

This media-based program has demonstrated ability to improve depressive symptoms with adults.[3,24]

The stress management module uses a six-session CBT approach[10,22] that trains users on different methods to deal with the thoughts, feelings, and actions associated with stress. The program introduces the concept of the "Stress Pyramid." The apex of the pyramid displays stress triggers and the base consists of thoughts, feelings, and actions (i.e., cognitions, emotions, and behaviors). The stress program includes content targeting each of the three areas at the base of the pyramid: a) "Weighing Evidence" exercises to teach cognitive restructuring; b) "Focused Breathing" to control emotions; and c) "Strategic Problem Solving" to select appropriate actions. The program includes briefings, cognitive restructuring exercises, interactive scenarios, and self-assessments.[1,22] Of note, the Expedition-APPP stress management module was only used in the first of the three pilot testing cohorts.

The conflict management module uses an interactive-media-based CBT approach[12] and an interest-based negotiation approach[26] to managing conflict. The program includes four elements: 1) an example conflict with information on how to reduce conflict, 2) a hypothesis testing exercise that teaches cognitive reframing, 3) an interactive exercise where users make choices to improve or worsen a simulated conflict, and 4) an interest-based, negotiation exercise that teaches negotiation skills. This last element (i.e., interest-based negotiation) was only available during the third and final pilot study cohort. The program introduces the concept of the "Conflict Cycle", which includes the elements of thoughts, emotions, and expressions and teaches users to "break" the cycle and foster healthy communication to reduce conflict.

The Virtual Reality (VR) module is based upon Attention Restoration Theory that suggests exposure to nature can reduce stress, improve mood, lessen fatigue, and renew productivity.[4] These natural experiences are not available to people living in an isolated or confined environments such as HI-SEAS, polar stations, submarines, or space craft. VR offers a way to transport crewmembers beyond the limited sensory exposure of the ICE and has been shown to reduce stress and promote relaxation in laboratory trials.[2] The VR program was not available for the first cohort but was utilized by the participants in the second and third cohorts.

Data Collection

The three pilot test deployments occurred in 3 sequential years. Lessons learned in each year were incorporated into subsequent deployments to improve acceptability (e.g., glitches were fixed in all modules, scenes were added to the VR system). The modules that were available during each pilot test are listed in **Table I**. Each of the crews were instructed to go through all the material in the conflict resolution and stress management sections at least once during the mission. In the first pilot test, participants were asked to complete all six sessions of the mood management module; in the subsequent two pilot tests, they were asked to complete the first two sessions of the mood management module but could continue through all six sessions if desired. After initial exposure, the crews were told to return to any of the modules as often as desired throughout the mission. For VR, the crews were instructed to view each scene at least once. They were encouraged to return to the scenes whenever they liked after the initial viewing. For each cohort, the crewmembers only had access to the modules after having lived in the habitat (i.e., the ICE) for a few months (details provided in Table I).

For each pilot test, participants engaged in two face-to-face, semistructured interviews at the completion of the mission and the study. The first was a group interview that focused on the technical aspects of the Expedition-APPP and VR programs. The second was an individual interview that focused on the acceptability and utility of the Expedition-APPP and VR programs. This analysis used qualitative data from the individual interviews; any discussion of technical difficulties associated with the studies were removed from the data set.

The interviews lasted between 28 and 52 min. The research team used an interview guide to elicit recollections of the various modules and the ways in which the participants applied any of the module content in daily life. The interviewer asked participants to share what they remembered from each module, what they thought of the content, the degree to which it was novel or familiar, and the ways in which they did or did not apply the module content in daily life while in the HI-SEAS habitat. A written list of the program modules and content was provided to aid recall. The interviews were transcribed verbatim by a professional service and the transcripts were uploaded into Dedoose software (www.dedoose.com).

Table I. Characteristics of the HI-SEAS Deployments.

PILOT STUDY COHORT	MISSION	CREW MALE/ FEMALE (N)	DURATION (MONTHS)	AGE (MEAN ± SD)	EX-APPP CONFLICT INTRODUCED IN THESE MONTHS OF THE MISSION*	EX-APPP STRESS INTRODUCED IN THESE MONTHS OF THE MISSION	EX-APPP DEPRESSION INTRODUCED IN THESE MONTHS OF THE MISSION	NATURE VR INTRODUCED IN THESE MONTHS OF THE MISSION
1	HI-SEAS III	3/3	8	31 ± 5	Months 4-6	Months 4-6	Months 7-8	N/A†
2	HI-SEAS IV	3/3	12	30 ± 4	Months 4-8	N/A	Months 9-12	Months 4-8
3	HI-SEAS V	4/2	8	27 ± 1	Months 4-6	N/A	Months 7-8	Months 4-6

* Interest-based negotiation portion of Ex-APPP Conflict module was only available for the HI-SEAS V mission.
† N/A = Not applicable as the module was not available to participants in this cohort.

Analysis

Our approach to the analysis was informed by Sandelowski[23] and followed the process described below. An initial coding scheme was developed by three members of the research team: a senior qualitative researcher (KDL), a coinvestigator (ASS), and an undergraduate student (JSL). Each of the three members independently read the same three transcripts and made marginal notations using self-generated codes to label the content descriptively. They then compared their coded transcripts, creating consensus regarding the names and operational definitions of the codes. The three team members used the resulting code book to independently code another set of three transcripts and met to review their coded transcripts and further refine the codebook. These iterations resulted in a codebook that had codes that were descriptive (e.g., "novelty" for talk about the degree of newness or familiarity in the programs; "emotional response" for talk about the impact of the programs on emotional state such as it being uplifting or relaxing or frustrating) or interpretive (e.g., "implementation" for content that would help us understand how to deploy the programs in the future in terms of accessibility or location of equipment, or timing of programs; "utility" for content that illustrates how the program materials were used in or relevant to participants' daily life).

Another team member (RMS) used the codebook to code all of the transcripts. The coded transcripts were then proofread by the first author who added and removed codes as appropriate. After reading each transcript, the first author created a memo for each transcript titled, "what did we learn from this participant?" The memos and the text coded with the "implementation" and "utility" codes were then repeatedly compared and contrasted to identify themes and corresponding insights that could answer our research questions.

The first author summarized the evolving analysis within a table that listed a theme within the data, a selection of quotations that exemplified the theme, and the proposed implication this theme could have for future implementation. The summary table was shared with the team who critiqued the evolving analysis. The second author reviewed and verified that each insight was supported by the data and returned to the team with points of confusion or ambiguity that were discussed and resolved at the team level. The resulting summary included two themes regarding the functions that the modules could serve and four themes describing barriers that could minimize the adoption and use of the modules.

To help us explore the representativeness of the themes (i.e., the degree to which the themes reflected views mentioned by many participants, versus a select, articulate few), we conducted the following audit of the data table. First, we looked to see how many participants had contributed exemplar quotations in our data table. Of the 18 participants, 17 had exemplar quotations, and most participants ($N = 10$) had 3 to 4 quotations (range, 0 to 8). We re-examined the transcript of the one participant without exemplar quotations to determine the degree to which the themes were apparent in his transcripts and added those to the table. As a second level of audit, we examined the degree to which the five themes were apparent in data from each of the three cohorts to confirm that the themes ran through all cohorts and were not only reflective of one cohort's feedback. The most articulate or illustrative quotations were then selected to appear in the following text.

RESULTS

Subjects

Ten men and eight women (i.e., the full sample of the three HI-SEAS missions) participated in individual interviews. Table I summarizes the average age of the samples and the modules that they viewed.

What Functions Could the Programs Serve for the Team and the Individuals?

Table II summarizes the following themes noted in the interview data and the resulting implications they could have for future implementation.

Expedition-APPP modules can provide shared culture, language, and tools for working through challenges. Participants indicated that the modules raised their awareness or provided a perspective on how to interact, communicate, and work with others. Many could identify either an idea or a skill that was presented in the modules that was relevant to their daily experience:

> So, I think it was very useful, especially because we were having some of the problems like discussed in the [conflict] module… it's related to skills that I have already, but it's a really good reminder. It pulls that stuff to the front of your brain instead of the back. [Study 3, ID 05].

> And that's where hypothesis testing came through… I said that, "Okay, if this is the case, uh, she would behave this way. If this was a different case, she would behave in a different way." And I think that helped me understand the whole situation better. [Study 1, ID 01]

> And so, the [depression] program helped specifically to look at it from a different perspective and to find ways – not to change her behavior but to change our perspective on it and what to do to not always be in the same cycle and to not be like, "We cannot do anything about it," actually actively thinking about, "Well what can we do to make life better for us?" [Study 2, ID 01]

Participants noted that the brainstorming and action planning steps in the mood management module could be applied to situations outside of the context of depression.

> A good one is sleep because that's a pretty easy example. I wasn't sleeping well for part of the mission… I was just up too late doing stuff with people and having fun. It wasn't a stress-based thing. And so, I liked that, working through it… actually, figuring out which solutions to pick of how to do that was really helpful because I couldn't, in my mind, make myself stop playing a game with my crew mates and go to bed. [Study 3, ID 04]

While the modules were designed as self-paced tools to build personal skills, participants indicated that some of the

Table II. Summary of Themes and Implications.

THEME	EXEMPLAR QUOTATIONS	POTENTIAL IMPLICATIONS FOR IMPLEMENTATION
Research question 1: What functions could the modules serve for the team and the individuals?		
Provide a shared culture, language, and tools for working through challenges	"…once we had all done that module, we all had the same language to use when we needed to solve a problem and say, 'I'm hearing this.' But what I'm trying to say is closer to this. Is that what you're hearing? And being able to actually use that visualization and that set of keywords with each other I think was really valuable. So, I like how we all had the same training. " [Study 3, ID 04]	a) Supplement individual, self-paced modules with content for groups or teams to explore together
	"…we've all done the same course. So, it gives us, at the very least, a vocabulary that we can communicate with." [Study 3, ID 02]	b) Add a section for how to identify others at risk for depression and how to support them
	"I can say that it came up a few times where [co-worker] said, 'Remember the virtual space station stuff. Say what it is you want. Don't beat around the bush. Just come out and say, 'This is what I want,'" [Study 2, ID 04]	
	"… when everybody's had the same training and you can actually just sit down instead of trying to coyly work it out, you just go "We should do the virtual space station." Like, "What is it about me that makes you want to punch me?" And you can just, like, start working through things and laugh about it and hopefully get some results without needing to be real psychiatrists or something." [Study 2, ID 06]	
	"…I didn't necessarily need to use it but was actually able to help [someone else] with some things saying, "Okay, I've been working with this…problem solving training. Let's try it with you," and was able to set some goals with her, get her working on some sort of short-term problem solving." [Study 2, ID 04]	
VR can allow access to experiences and emotions that are currently inaccessible	"…and I think that's kind of what's nice. You don't get the variety of experiences in your day to day life in the Hab. So, to have something that gives you a little bit of a new feeling, a new experience, a new place is kind of cool." [Study 3, ID 02]	a) Tailoring to own preferences is desirable (geography, animals, urban versus rural scenes)
	"I think I would have gotten more out of it if I had more videos that were more tied to memories and locations that I cared about because it's not so much the experience that you're getting; it's not, "Oh, wow, I don't know I'm in this room anymore." It's more, "I'm thinking about this family, and these people who I've shared joyous experiences with, and have taken care of me," and things like that." [Study 3, ID 03]	b) Need multiple options for use e.g., stimulation, relaxation, socialization
	"But I thought they were cool because it kind of – I remember first putting that on in the city scenes and thinking, "I've not seen this many people for a long time." [Study 3, ID 06]	
Research question 2: What barriers would need to be addressed to facilitate use of Expedition-APPP modules and VR?		
It is easy to forget the content or not remember to use the content when you need it	"I just forgot to do that and I think having a reminder or having something… They should have said, 'Maybe you should go back to this stuff again, just as a reminder. I know it'll take time out of your day, but maybe it'll help you.' So, we should have thought of it too. I mean, it was available, it wasn't like it wasn't there for us to use. We just didn't." [Study 2, ID 02]	a) Find way to make it part of routine
	"You find that in some of the tools where they have really good content, and it's just buried under ten layers of normal, everyday stuff, so it becomes difficult. You can't just go on and extract what you need." [Study 3, ID 03]	b) Cues to revisit
	"I think it was mostly because we had sort of the couple of sessions and then we never came back to it. So, we got sort of the initial training on it but not sort of any recurrent training to help keep it infused as we went on throughout the mission." [Study 2, ID 04]	c) Make it easily accessible as opposed to only in the computer or embedded in programs (rapid access to tools in program; handouts or flyer on wall)
		d) If mandating booster sessions, present different content or examples

Table II, *Continued.*

THEME	EXEMPLAR QUOTATIONS	POTENTIAL IMPLICATIONS FOR IMPLEMENTATION
People have varying ways of conceptualizing and coping with stress and depression	"And so, doing something that's trying to kind of help me deal with problems… I already kind of feel like I sort of know how to deal with, it kind of felt like I was doing something that just wasn't that helpful for me personally." [Study 3, ID 06]	a) Revisit the name and marketing of the depression module
	"So, um, stress management, I didn't find it too helpful, either, because I have my own ways of dealing with stress if I have stress." [Study 1, ID 01]	b) Expand to approaches beyond PST
	"I noticed the module itself is called mood and not depression. And I think that was a good choice because I think it helps alleviate some of that weird, inherent ickiness people have talking about depression, even if it's true." [Study 3, ID 04]	c) Provide menu of mood-boosting activities and how to maximize their potency
	"I felt the sort of forced journaling stuff was always good…And that was something… that I started anyway and so that sort of was an idea that I had already had and so having [Expedition-APPP] tell me to do it I felt was a useful tool, that it might help me sort of get through my thoughts… We did a lot of workouts and yoga and stuff like that, also. I always find that kind of calm, meditative time useful." [Study 1, ID 03]	
If depressed, a computer-based program demands a lot of internal motivation and initiative.	"It's good information. The doctor who's doing the talks and stuff, he's pleasant. He's easy to listen to. It's a good thing. It's just I don't think it's very practical for someone who is actually depressed, like to that – like maybe if somebody's feeling a little bit down, let's go check it out, you know. But again, if you're just feeling a little bit down, usually you're able to bring yourself out of it by going and doing something that you enjoy or something like that. And really, it looks – it feels like the program is kind of geared more towards the people that are getting far down, who are getting to point where they're losing functionality in their daily life because it's all about creating a plan and let's problem-solve and things like that. But when you're there, when you're at that point, you actually have to turn on your computer and actually get through that stuff." [Study 1, ID 06]	a) Offer ways to foster interaction as opposed to pure self-direction
	"But, like, the first time we went through it, it took over an hour, and it's like, you know, like, myself, too, I'm like, 'Well, I can't really see someone who's really depressed making themselves do the problem-solving treatment in the first place.' Because it was just, like, little tasks become so hard to do when you're depressed, that sitting down for a whole hour and going through everything is actually a really big task." [Study 1, ID 05]	Stepped approach to depression care (e.g., start with behavioral activation, move to problem-solving treatment)
	"I kind of wish that there'd have been a little more feedback um, because when you go to the sections and stuff and part of what I thought the depression um, one I would've benefited from a lot is if you could you know, go through the session and make it through and have a little report and everything and if you could actually like send that to someone and then like get actual feedback from the person or from or something instead of just having like this is what you said you're gonna do and this is your action plan and everything and I'm like yeah, I know that, I'd just move back like but I'm not, it's just like more a dialogue, something that could be used two ways than just one way." [Study 1, ID 02]	

content provided a shared language a team can use to catalyze effective communication.

> I remember very specifically, we had a conflict about something and one of the crew members referring back to the conflict module. And there was a diagram in there where it's like I say something, and you assign meaning to it. And then, you reply based on the meaning. And so, we actually had a conversation where we used that sort of [to] describe what we felt like was going on within the crew. So, I thought that was useful. And that diagram was something that we definitely went back to... [Study 3, ID 02]

One participant noted that it would be valuable to have guidance in how to recognize the symptoms of depression in others and how to support that person. Two other participants expressed an interest in supporting a friend who they worried was experiencing depression and specifically attempted to use content from the Expedition-APPP in that manner:

> I kind of went through the problem-solving treatment and made notes for myself, like, what the steps were and how might I get [friend] to, kind of, do these without, like, forcing him to do the program. [Study 1, ID 05]

VR can allow access to emotions and experiences that are currently unavailable. The VR component was conceived as a mechanism for restoration; a way to disconnect from stressors of work and access nature in a setting where nature is inaccessible. While most people enjoyed the nature scenes and some did find the programs relaxing enough to induce sleep, many did not necessarily indicate that relaxation was their primary intent when engaging with the VR. Many participants said they were looking to the VR technology to provide them with emotional or sensory experiences that they could not access in the confined location, like seeing familiar places or animals, or flying in an aircraft.

> It was good to have the experience. Yes. I was kind of under the understanding that I wasn't gonna get to fly for a year anyway but it was nice to have that as sort of a reminder to be able to at least have somebody else flying me around, if only virtually. [Study 2, ID 04]

> …the Oculus demo thing where it puts you on the side of a building – that's not necessarily a relaxing experience, but you get that gut trap – you get a sensory input that you might not have otherwise in a habitat. We're limited in the things that we feel. So, even if it's something that makes you feel scared or excited, those are interesting tools. It just gets you feeling emotions that you might not feel otherwise. [Study 3, ID 03]

In particular, some suggested an interactive component of VR could enhance the experience further. Sometimes that meant interacting with the images within VR, such as being able to move around and pick up objects.

> The idea is to be transported right? This is a transportative medium, you wanna be projected into the scene. But if you can't interact with the scene, though the scene clearly is meant to be interacted with, there's stuff on the desk, there's cards, there's a light, you wanna press the buttons but you can't. I think that was a clear deficiency. [Study 2, ID 05]

Sometimes participants expressed a desire for social interaction. For example, wishing they could use the technology to connect with family.

> I think it might be almost the most valuable way to stay connected to family and friends back home because there's no other way to actually feel like you're there unless you are walking through a video… But if you could send a 3D video of someone walking around – I think of my nephew running around in the backyard and playing, you would feel like you're actually with them at the time, even if it's delayed and it comes in a little bit later, it's still a video of things going around you. You could move your head around and stuff. That would be super cool." [Study 2, ID 02]

Or some teams subsequently downloaded games to play within the VR equipment that allowed them to socialize with each other in a different manner than sitting around a table.

> Basically, people have these manuals with a bunch of puzzles to solve, and one person puts on the headset, and you have this little bomb in front of you, and you have to communicate what's on that device, and they have to communicate how to solve the puzzles, and you're working together. That was an interesting use of it where you could actually have several people involved. A couple of us used that in our recreational time as well. [Study 3, ID 03]

What Barriers Need to be Addressed to Facilitate Use of Expedition-APPP Modules and VR?

It is easy to forget the content or forget to use the content when it is needed. While many people could cite examples of skills or perspectives that were conveyed in the Expedition-APPP modules, almost everyone indicated that it was often difficult to remember all of the details about the content or techniques.

> The issue that I had with it is, and it's not an issue with the program itself or any of the content, it's just that I didn't even think about the stuff that I learned in the module unless it was like right after… It all just kind of went away as time passed. [Study 1, ID 06]

Many suggested booster sessions to refresh memory, while acknowledging that revisiting the same content would not be rewarding; new content and new examples would be preferable. Some noted that print copies of materials would be valuable, as would rapid access to the sections that contained the actual tools or strategies.

> …because it's sort of a training program but maybe some other way like to quickly access what you want and maybe it was in there and I didn't do it properly but it was kind of like a lot of um, like lecturing kind of and going through the whole training but if there's a way to just like pull out that tool box and use it like on this problem now but I don't know which module and where to like get to that part of the tool." [Study 1, ID 04]

People have varying ways of conceptualizing and coping with depression and stress. Participants had varying degrees of appreciation for the Expedition-APPP modules. One perspective raised by participants was that most people already have "go-to" coping strategies that were not reflected in the modules.

> I think, in a lot of ways, we've sort of gotten to where we are because we've learned how to deal with stress. And we've learned how to cope with things. And so, then, to have a computer program nitpick at the way that I do it is just kind of not appreciated, if you will. I found that frustrating. [Study 3, ID 02]

There were also varying degrees to which those strategies were accessible in the environment.

> "Not really, but it was just because we were isolated in this dome and what we had was what we had. It wasn't like I could go to Walmart and buy a new board game… It was like, this is what we have for eight months, so you know, not much variety. You know, there's only so many things you could do. So, like, again, I guess you could brainstorm some new things, but I don't know. I pretty much knew the things I found enjoyable in the dome at that point." [Study 1, ID 06]

The mood management module leads participants through an evidence-based treatment for depression. At least one participant felt the label of "depression" could be stigmatizing.

> I think the only other thing I didn't really enjoy was some of the word choices. I feel like you probably are aware depression has a very specific kind of connotation. And when you have really aggressive, high functioning people, that's an insult to say you're depressed, even if it's true. [Study 3, ID 04]

If depressed, a computer-based program demands a lot of internal motivation and initiative. Some participants questioned the feasibility of relying upon a computer program when depressed.

> I did actually become pretty depressed while we were in the dome, going to a computer and watching videos and it's the last thing I wanna do, if I'm depressed. Even your thoughts in your head are like, "Man, I should really do that," but you just can't make yourself. Like I don't even wanna get up out of my bed, so I'm obviously not gonna wanna go and invest time on this module.. …when you're talking to an actual person, there's that emotional connection like this person is really trying to help me feel better. A computer's not trying to help me feel better. It's an inanimate object. So, it's all on me to get stuff out of the computer and when I'm feeling depressed… [Study 1, ID 06]

The program was perceived as requiring a lot of time and effort, as well as internal drive, to follow each step.

> …then you work on solutions and sometimes it's a bit frustrating when you're brainstorming and have this list of ideas and then have to go through all of them and have to click for every single one of them… and it's very time consuming if you have a very long list. And then after the third time, you learn to keep the list short because then you will never be done. [Study 2, ID 01]

> But, like, the first time we went through it, it took over an hour, and it's like, you know, like, myself, too, I'm like, "Well, I can't really see someone who's really depressed making themselves do the problem-solving treatment in the first place." Because it was just, like, little tasks become so hard to do when you're depressed, that sitting down for a whole hour and going through everything is actually a really big task. [Study 1, ID 05]

DISCUSSION

The Expedition-APPP and VR systems were designed as countermeasures to the challenges that come with living in isolated and confined environments. Such countermeasures are critical in the context of long-duration spaceflight. The aim of this analysis was to generate insights that would guide the further development and future implementation of this suite of programs as well as to guide others working on behavioral health countermeasures in ICEs. The first theme noted in these data was that the modules provided a common language for the team. This idea of a shared language or "team talk sessions" has been discussed by Kass and colleagues[18] as a potentially useful psychological countermeasure for people living and working in ICE. In developing the Expedition-APPP further, this feature could be exploited to maximize the potential benefits. For example, it would be interesting to explore opportunities to supplement the self-paced nature of the Expedition-APPP module with an opportunity to process some content as a team or a group; this may encourage the use of actual tools within the modules by the team as a whole. Such preflight team training regarding psychosocial skills has been proposed as a crucial component of preparation for long-duration spaceflight.[16] Responding to how at least two crewmembers used the program, it may also be valuable to add content regarding how to support others struggling with depression. Modifications such as this would leverage the power of group support and peer support that is seen in many mental health programs.[21]

The second theme illuminated the participants' feedback regarding the potential uses of the VR content that has implications for implementation. Opportunities to tailor the choices within VR is highly desirable, in order to align with preferences in terms of the type of nature being presented, e.g., types of animals or landscapes. Of the scenes available to the crews, the high-definition nature scenes were preferred.[25] Perhaps most intriguing, however, the participants wanted to use the VR system to experience cognitive stimulation, emotional arousal, and/or social interaction. Some participants were intrigued by the urban scenes, as they exposed them to crowds of people that were absent from their current environment. Some participants enjoyed the interaction that VR could provide via gaming. Attention Restoration Theory[4] posits that nature provides psychological distance from routine mental concerns (i.e., a sense of "being away") combined with effortless, interest-driven attention ("fascination"), supported by an environment of substantial scope ("extent"). Our data suggests that ART may be but one lens through which we can understand and evaluate the role of VR in isolated and confined environments. As research develops regarding the benefits of VR gaming,[11] it warrants investigation to determine whether gaming via VR could also be a useful part of these countermeasures.

Other themes in the data revealed potential barriers to use that will need to be ameliorated in future implementation of the programs. In order to be maximally useful, it may help to supplement the computer material with handouts or posters that could be accessible without technology. Similarly, a way to access the tools directly in the modules without needing to review the entire video content is also desirable. Both a virtual and physical library or tools and resources might allow the most accessibility, though the feasibility of that in confined spaces is limiting. A timing schedule and cueing to revisit the content is also likely necessary in order to avoid a "one and done" or "out of sight, out of mind" mentality toward the programs.

Because the participants generally had favorable views of the educational portions of the Expedition-APPP, it may be helpful to augment the Expedition-APPP with information about a large variety of active coping strategies and ways to make them maximally potent, for example, optimal dosing of exercise[5] for mood modification. A catalog of stress and mood-managing activities that are available to participants within a particular environment could enhance the ability of people to personalize

their experience within the Expedition-APPP. Finally, some social component or peer support may need to be infused into the programming to foster uptake and ease of use within the actual context of depression.[20]

Limitations

Ours was not the only study occurring during the HI-SEAS deployments. On two deployments, participants were also exposed to another, similar computer-based educational system that was being tested. There was overlap between the systems as they both contained psycho-education regarding stress and problem-solving. As a result, there may have been more survey fatigue or feelings that content was redundant than would have been reported if either program was tested in isolation. Also, the salience of the crewmembers' recollections about what they thought of each module may have decayed with time and could have been affected by differential exposures (e.g., one viewing vs. multiple viewings; two sessions of the depression module vs. all sessions). As such, there are likely perceptions and feedback that we missed because we could only interview crewmembers after the deployment ended, as opposed to immediately after viewing the material. Finally, the modules and VR content were iteratively refined between each round of pilot testing and not every cohort was exposed to every module (e.g., only the first cohort reviewed the stress management module as shown in Table I). Those contextual features were important when interpreting the idiosyncratic feedback about our programs, but are less worrisome in this analysis, where we are focusing less upon what was liked or disliked, and more upon aspects that affect implementation of any computer-based mental health program.

Conclusion

Both the Expedition-APPP and natural-scene VR are self-directed, behavioral health tools that can be used autonomously and anonymously to maintain psychological well-being in ICEs. Quantitative survey results show that the programs and VR score well for usability, acceptability, and perceived value. The qualitative results presented here, however, provide additional findings needed for optimizing these autonomous behavioral health tools. An unappreciated benefit of the programs was their ability to provide a shared language for all the crewmembers when dealing with group conflict. As such, it might be helpful to use the modules to provide training prior to a team's deployment to an ICE. The need to provide quick, engaging, and easy to access refresher training was highlighted. The problem-solving approach in the depression program was useful for users, but the frequent mentions of depression in the program and the effort involved were seen as drawbacks. Additional VR content, beyond the natural scenes, was seen as desirable. For long-duration exploration missions, self-directed and autonomous tools will be needed, and these results provide guidance on how those tools should be structured.

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