An Interactive Media Program for Managing Psychosocial Problems on Long-Duration Spaceflights

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Space crews must be self-reliant to complete long-duration missions successfully. This project involves the development and evaluation of a network of self-guided interactive multimedia programs to train and assist long-duration flyers in the prevention, assessment, and management of psychosocial problems that can arise on extended missions. The system is currently under development and is intended for use both during training and on orbit. A virtual space station 3-dimensional graphic was created to serve as a portal to multimedia-based training, assessment, and intervention resources. Additionally, original content on interpersonal conflict and depression is being developed for the system. Input on the best practices for managing conflict and depression on extended missions was obtained from 13 veteran long-duration flyers, as well as from clinical experts. Formative evaluation of a prototype of the system will be conducted with 10 members of the astronaut corps. Subsequently, the content on conflict and depression will be completed, and the depression self-treatment portion will be evaluated in a randomized controlled trial. Although this study involves developing countermeasures to assist long-duration flyers, it also provides a model that could be applied in many Earthbound settings, both in operational environments and in everyday life.

Keywords: spaceflight, multimedia, interactive, psychological, psychosocial, psychiatric, training, intervention, assessment.

MANAGING DEMANDING workloads in space, where the operational environment is simultaneously isolated yet crowded, and monotonous yet dangerous, can tax individuals' abilities to cope. Stress-release opportunities, social support, and enjoyable activities that are routinely accessible at home may be unavailable on long-duration spaceflights. Annoying interactions that would ordinarily be shrugged off can escalate into serious interpersonal conflicts (26). Furthermore, crewmembers may feel that they have insufficient control over their lives due to the limited options onboard and to the scheduling of their time by Mission Operations. When individuals feel powerless to influence their environment and control their lives, learned helplessness can result and provide a direct pathway to depression (9,68).

The literature on psychosocial problems in space is limited and consists largely of anecdotes, memoirs, and media accounts. Nonetheless, it is clear that conflict (40,49), depression (36,60,72), and cross-cultural misunderstandings (35,37,45) have occurred on long-duration spaceflights. Additionally, anxiety reactions, though not yet reported on long-duration missions, have occurred on shorter spaceflights (60). Although rare, psychosocial problems have the potential to impinge on mission objectives and crew safety. The potential impact of these problems becomes even more severe as crews venture further from Earth, (e.g., to the Moon and Mars), where evacuation will be dangerous, costly, and, at times, impossible.

Organizational, operational, and interpersonal factors can contribute to psychosocial problems. Crowding, time pressure, shifting sleep schedules, frustrating procedures, interpersonal competition, unclear lines of authority, and miscommunication with ground personnel can increase the probability that otherwise robust crewmembers will experience psychosocial problems (37,38). Therefore, a multifaceted approach to maintaining crewmembers' psychosocial health is needed that: 1) addresses the organizational problems that can create tensions for the crew; and 2) provides individuals with resources and countermeasures to cope successfully with the unique environment. The current project focuses on individual-level countermeasures.

Existing individual-level countermeasures for preventing and managing psychosocial problems consist of preflight training, private video and audio communications with family and friends, and counseling by ground personnel as needed. Additionally, the ground psychological support team provides logistical and emotional assistance to flyers' family members to help manage problems at home that could intrude on mission performance. Despite the availability of these resources, NASA still rates "human performance failure because of poor psychosocial adaptation" as a top-level risk to the success of long-duration missions (64).

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Several barriers deter astronauts from requesting help from the ground for psychosocial problems. First, they may feel that privacy will be difficult to maintain in space-ground conferences: the flyer may be overheard by other crewmembers, communications may be intercepted, and persons on the ground may inadvertently hear them. Holland (36) has emphasized the difficulty of ensuring the privacy of such conferences, while noting that encryption technology is reducing the likelihood of transmissions being intercepted by third parties. Second, a crewmember might believe that reporting a problem to the ground could impact his or her potential to be selected for future missions (71). Third, because astronauts are stereotyped as being tough and capable of handling any situation, sensationalistic reports may result if the press learns of problems. Negative publicity can overshadow the flyer's accomplishments and damage the reputation of the astronaut corps. For these reasons, crewmembers may resist seeking assistance until absolutely necessary. If, however, resources exist on board that can be accessed privately and discreetly, refresher training and assistance with the prevention and management of psychosocial problems could be provided at the time when it is most needed. Whereas the threshold for requesting assistance from the ground is high, it is anticipated that the threshold for using a self-guided system will be low.

An interactive multimedia system, the Virtual Space Station, is being developed to serve as a portal to computer-based resources for the prevention, assessment, and management of psychosocial problems. Two training and intervention programs are under development: one focusing on depression and the other on interpersonal conflict. The strategy is to address higher base-rate behavioral problems first and then expand to those that are less common but still potentially disruptive. A brief review of the computer-based training, assessment, and behavioral intervention literature is provided below, followed by a description of the countermeasure and its development process.

Computer-Based Training

Self-instructional training is not a new concept. Books have been written for centuries to teach skills, and instructional video and audiotapes have been available for decades. However, the more interactive a training experience is, whether live or self-instructional, the more effective (19,57) and satisfying (85) it will be. Unlike earlier media, computers can provide highly interactive training with immediate feedback that is paced and tailored to the learner's needs. Moreover, multimedia training, which incorporates audio and pictures, has been shown to be more effective than computer training using only text (56).

Studies comparing computer-based training to other self-instructional modalities have generally found computer training to be more effective due to its higher level of interactivity. For example, a recent study by Eckerman et al. (19) randomized 123 adults to learn how to use respirators via one of the following: 1) a book, 2) reading text on a monitor, 3) interactive computer-based training, or 4) passively viewing the work done by participants in the interactive group on separate monitors but without interacting with the program (a yoked control condition). Although the same training content was presented in each condition, participants who could interact with the computer scored significantly higher than all other groups at immediate, 1-wk, and 2-mo post-tests, indicating that they had both greater and more durable knowledge.

In many cases, computer-based training can also be made more interactive—and consequently more effective—than live training, which often consists of lectures. For example, the FBI (66) compared stand-up training in basic counterintelligence skills to a self-instructional course that incorporated computer-based training, videos, and manuals. Not only did trainees in the self-instructional condition score 20% higher on a knowledge post-test than those in traditional training, they completed the course in only 37% of the time required for stand-up training.

The use of video, audio, animations, graphics, and photos in computer training enhances learning outcomes. A predecessor to modern interactive multimedia was interactive videodisc (IVD), which used a personal computer and videodisc player. A 1994 study by Martin et al. (55) compared the effectiveness of teaching workplace negotiation skills by three methods: 1) IVD; 2) a facilitator-led group using videotapes; and 3) workbook and video only. Knowledge acquisition and learner interest in the training were equivalent in both the IVD and facilitator-led groups and significantly higher than in the self-instructional workbook and video group. The similar results between the IVD and facilitator-led groups are striking, considering that learners in the latter group participated in discussions and answered questions in their own words, which was not possible in the IVD group.

Large-scale studies have reached similar conclusions. In a meta-analysis commissioned by the Department of Defense, Fletcher (20) compared IVD training to conventional training. IVD training was more cost-effective, and equally effective for teaching skills, procedures, and facts. Furthermore, in a recent review of 12 meta-analyses of the effectiveness of IVD and CD-ROM multimedia programs in education, Kulik (47) concluded that adult learners using multimedia required 24% less time to learn materials than those in classrooms. College students required 34% less instructional time.

Although the effectiveness of multimedia training has been well established, little research comparing the relative effectiveness of different interactive media instructional designs has been conducted. Therefore, the choice of instructional design is made largely on theoretical grounds, as well as learners' reactions to programs they have used. An innovative instructional design pioneered by Henderson (33) for interactive media-based professional education is the Virtual Practicum Model (VPM). The VPM is nonlinear, embedding training experiences in a graphical, virtual representation of the learner's work environment, whether that is a clinic, neighborhood, or space station. Users can explore and work in the environment by clicking to enter various locations, each of which contains different types of training activities. Key components of the VPM are simulations, learning activities, a resource library, interviews with persons who have relevant experience, brief didactics, and guidance from a mentor who is both a master practitioner and an effective teacher. The VPM has been used to teach a wide range of professional skills, including counterterrorism techniques (31), genetic counseling and testing (28), HIV prevention counseling (32), HIV and AIDS treatment (29), and smoking cessation (30). It has also been used to teach cancer patients how to manage the side effects of radiation and chemotherapy (34). Anecdotal reactions from professionals who have used VPM programs have been extremely positive, and it is a good fit for the countermeasure under development. As astronauts already use computer-based training on the International Space Station (ISS) (65), the present study expands the breadth of material that can be taught by this modality.

Computer-Based Assessment

Studies of computer-based assessments in medical and mental health care have involved comparisons either to interviews conducted by live clinicians, or to paper and pencil measures. Patients generally have positive reactions to computer assessments and report them to be acceptable, interesting, and informative (54,81,82). As early as 1966, Slack et al. (82) found that patients report more medical problems in computer assessments than in interviews conducted by clinicians.

This finding has been corroborated by Locke (51) and others (43,83). Moreover, compared with persons interviewed by healthcare providers or counselors, individuals who are interviewed by computers acknowledge a greater number of potentially embarrassing or socially unacceptable behaviors (51,81). In a recent review, Marks (54) noted that patients report higher levels of comfort and provide more information to computers than to clinicians about drug and alcohol use (17,44,79), sexual behavior and problems (43), HIV risk behaviors (51), and suicidal ideation (24,69). Two primary factors may account for this difference. First, comfort levels may be higher when revealing sensitive information to a computer. Individuals may perceive the computer as nonjudgmental, whereas they may engage in self-censorship with live interviewers because they expect to be judged. Second, a computer does not inadvertently skip or prematurely branch out of lines of questioning. For example, a live interviewer might not ask an elderly patient about illicit drug use, assuming, based on demographics or demeanor, that it is not a problem. A computer would not omit such questions if it were programmed to ask them.

Studies comparing paper-and-pencil to computer versions of the same multiple-choice assessments have predominantly found them to be equivalent in terms of reliability, validity, and acceptability. Such comparisons have been made for measures of depression (75), generalized anxiety (76), obsessive-compulsive disorder (70), and phobias (12).

Computer interviews do have drawbacks. Their ability to understand natural language (freely typed or spoken responses) is minimal, which restricts assessments to multiple-choice answers unless a human is available to interpret language-based responses. Additionally, computers cannot observe nonverbal behavior, although Slack has studied response latency as an indicator of uncertainty and changes in heart rate as a measure of anxiety about answering questions (80). Nonetheless, the advantages of computer assessments may outweigh their shortcomings, particularly in settings with few alternatives, such as long-duration space missions.

Computer-Based Behavioral Interventions

On Earth, self-help interventions provide convenient, cost-effective, and generally efficacious treatment to individuals who may not otherwise seek help for minor to moderate psychological problems (53,58). On long-duration spaceflights, self-help tools accessible via computer could support astronauts in managing their own problems, thereby reducing the need for evacuations or other major interventions by the ground.

An early study by Selmi et al. (78) compared cognitive-behavioral therapy for depression administered by a text-based computer program to the same treatment protocol administered by a therapist. Treatment consisted of cognitive therapy, activity scheduling, and education about depression. A total of 36 participants were randomly assigned to computer, therapist, or wait-list (control) groups. Outcome measures indicated that patients using the computer made treatment gains equal to those of patients attending six sessions of clinician-guided therapy and improved significantly more than those assigned to a no-treatment control group. Additionally, patients were equally satisfied with computer-based and live therapy.

Greist et al. (25,67) have developed a computer treatment for depression that involves a videotape and workbooks plus telephone calls to and from a computer that accepts touch-tone or voice input in response to multiple-choice questions. The computer administers depression assessments with data entered via touch-tone phone and, based on users' responses, provides instructive and supportive prerecorded audio messages and homework assignments. Patient education, cognitive therapy, activity scheduling, and assertiveness training are included among the skills covered in the 11 telephone calls and 9 booklets. In a pre-post trial, 68% of the 41 study participants completed the 12-session self-treatment protocol. Of those who completed the protocol, 71% met criteria for treatment response (Hamilton Depression Rating Scale score ≥50% improvement) (67).

Several self-treatment computer programs have also been developed for anxiety. In 2001, Carlbring et al. (11) developed an Internet self-treatment for panic disorder. They converted a manual-driven, therapist-administered, well-validated cognitive-behavioral panic disorder treatment into an interactive self-help format. The computer intervention included patient education, cognitive therapy, breathing retraining, and exposure therapy. Treatment was delivered over 7 to 12 wk via a computer-led protocol supplemented by e-mails to evaluate participants' understanding of each treatment module. A total of 41 persons with panic disorder were randomly assigned to a treatment group or a wait-list control group, and only 5 (12%) dropped out. Individuals in the treatment group showed significantly more improvement than those in the wait-list condition on 13 out of 15 measures of anxiety, depression, and quality of life.

Klein and Richards (42) also studied Internet treatment of panic disorder. In a randomized controlled trial comparing self-administered treatment to a wait-list control, participants who used the website reported significant decreases in panic frequency, anticipatory fear of panic, general anxiety levels, and body vigilance. They also reported increased self-efficacy in managing panic attacks. No significant changes in the control group were found during the same period.

Beyond being effective, most reports have found self-help interventions to be empowering and acceptable (77). The short but promising history of computer-based assessment, training, and behavioral interventions suggests that the system under development will meet needs both in preflight training and on long-duration missions.

METHODS

Countermeasure Description and Development Plan

The self-guided nature of the Virtual Space Station is designed to increase the independence, resilience, and self-reliance of long-duration flyers and augment the existing support structure for managing psychosocial problems. The completed system will contain a network of programs serving multiple functions, including self-guided training on the prevention and recognition of psychosocial problems, self-guided assessment, self-guided behavioral interventions, and educational support for crewmembers-turned-care providers. The system will be delivered on a DVD-ROM, and each astronaut will be provided a copy to use at will during training, as well as on long-duration missions.

Astronauts are busy, function at a high level, and have a low rate of psychosocial problems. For them to utilize the countermeasure, it must be usable, acceptable, credible, captivating, and confidential. Usability is maximized by incorporating simple navigational interfaces that contain a minimal number of choices per screen. The primary interface is a three-dimensional graphic of the ISS with five modules labeled Simulator, Interventions, Self-Assessment, Resources, and Data to reflect the type of content each one contains (**Fig. 1**). When users click on a module, a quick animation "flies" them into it, where they can choose from a set of topics and activities. This method of navigation is a form of zooming interface, which has been demonstrated to be among the most effective designs for helping users keep

Fig. 1. The top-level portal interface of the Virtual Space Station.

their bearings in complex programs (4,39). Usability is also enhanced through audio instructions and "roll-overs," in addition to text and visual cues. Usability testing is being conducted throughout the development process.

Acceptability is promoted by creating believable training scenarios that are not perceived as contrived or inaccurate, yet do not recreate specific incidents. To develop realistic simulations, 13 veteran long-duration flyers were presented with potential training scenarios and asked to comment on their realism and how they could be improved. Their suggestions were applied in the creation of the training simulations. These interviews are further described in the Development and Evaluation Process section.

The literature on how users judge the credibility of websites is applied in the current project. Websites are judged to be credible if they cite trustworthy sources with relevant expertise, are easy to use, and have a professional look and feel (21). In the Virtual Space Station, experts who are nationally recognized in their respective fields serve as on-camera mentors, or coaches. As described below, Dr. Leonard Greenhalgh is an expert in workplace conflict management training and Dr. Mark Hegel specializes in problem-solving treatment for depression. Although the astronauts may not previously know of these individuals, it is anticipated that their backgrounds will provide sufficient credibility for their messages to be received positively. The other aspects of credibility—ease of use and a professional look and feel—are addressed by incorporating proper interface design and high production values.

A program—or an instructor—must entertain in order to educate. If a program is dull, trainees won't use it, just as students will tune out a boring lecture. Teaching through narratives and creating a sense of "presence" in a virtual world are two techniques to make the Virtual Space Station captivating. Besides holding the learner's attention, teaching skills through stories has been demonstrated to be more effective than presenting them abstractly or out of context (73). For these reasons, narratives are incorporated at several points. Through simulations, users learn concepts and practice skills by playing the role of a crewmember interacting with videotaped actors. Additional narratives will be provided through: 1) videotaped interviews with veteran flyers (recorded subsequent to the 13 initial, confidential interviews) providing advice and anecdotes about their experiences on long-duration missions; and 2) mentors (Drs. Hegel and Greenhalgh) telling stories to illustrate teaching points. The system supplies further narrative content by including a number of full-length books on the psychosocial topics covered, as well as books detailing early exploration expeditions.

"Presence" is the ability of a computer program to produce a sense of being in and interacting with an environment different from the user's actual setting (74). The sense of being present on a Virtual Space Station is created through an interface graphic that resembles an actual space station—actually, a slight variant of the ISS—in which users can move in and out of modules by clicking on them, similar to a sophisticated video game. Presence is also fostered through mentors and actors using "I" and "you," and addressing the video camera as if they were speaking directly to the user to create a sense of being engaged in a conversation. Besides enhancing the sense of presence, "personalized" multimedia programs, in which on-screen agents speak directly to the user, have been shown to produce training outcomes superior to non-personalized programs in which the user is an observer (59). This technique also enables nonverbal communication to be perceived, providing a richer experience than would be possible with a program that used only text and graphics. Similar to engaging an audience in a captivating movie, the design goal is to make users feel more like they are interacting with people on a space station and less like they are interacting with a computer.

Data security is one of the most important characteristics of the system. In order to obtain maximum value, crewmembers must be confident that their use of the system is not monitored and their responses are not shared. To facilitate this trust, data are encrypted and password protected. Only users can access their data, and they can choose which information to save. On Earth, data will be stored on the user's hard-drive, and on orbit it will be stored on an on-board fileserver.

Virtual Space Station Modules

The Simulator module is dedicated to training in the prevention and management of psychosocial problems. When users click on the Simulator module, they quickly "fly" into the module, view the interior, and are presented with a graphic of a checklist binder identical to those used on board the ISS. Users select a topic to learn about from the checklist, which currently includes conflict management and depression.

When conflict management is selected, the checklist binder opens to a list of training simulations that are available on that topic, as well as a "10-min Briefing on Conflict Management." Users are encouraged to "attend" the briefing before moving on to the simulations,

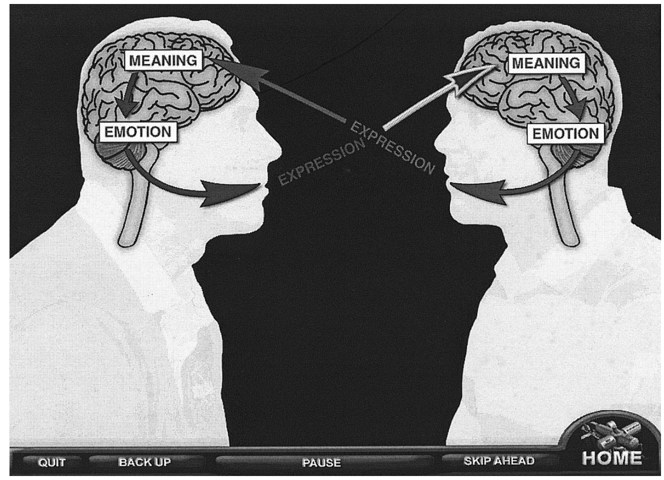

Fig. 2. The conflict cycle.

although they are free to engage in learning experiences in any order they wish. The 10-min Briefing on Conflict Management uses video, audio, animations, and text to interactively teach a cognitive-behavioral framework for understanding conflicts based on Greenhalgh (23). Users are introduced to the conflict cycle (**Fig. 2**), which depicts conflicts as consisting of: 1) things individuals do and say (observable behaviors); 2) their interpretations of the other person's behaviors and the overall situation (their cognitions); and 3) the emotions that follow from these cognitions, which tend to drive response behaviors. Users are taught to intervene in the cycle by changing what they are saying or doing, checking that the meanings they are attributing to the other individual's behaviors are appropriate considering their context, and managing their own emotions, so that anger or other negative moods do not control their response behaviors. This approach to conflict management was chosen because it fits with the informal training that astronauts already receive in conflict management and because cognitive-behavioral approaches to conflict have been empirically supported in a variety of settings (10,18,84,87).

Conflict simulations in the Simulator module enable users to practice behavioral means of breaking the conflict cycle. Techniques for evaluating the meanings assigned to others' actions, i.e., cognitive restructuring and managing emotions, are covered in the Advanced Training section of the Resources module. The prototype conflict management simulation depicts an overt dispute that escalates rapidly. In it, a professional actor, appearing on video, plays the role of an astronaut and speaks directly to the camera as if talking to the user (**Fig. 3**). This fictional crewmember has accidentally shut down an ISS computer system by unplugging a cable and asks the user—who is put in the role of a fellow crewmember—not to tell Mission Operations what happened. At critical junctures, users are able to choose what to say to the crewmember from menus of three choices. The video narrative branches based on the users' decisions, with 12 possible endings. The endings range from capitulating to the astronaut's request, to negotiating with him, to ignoring the request and

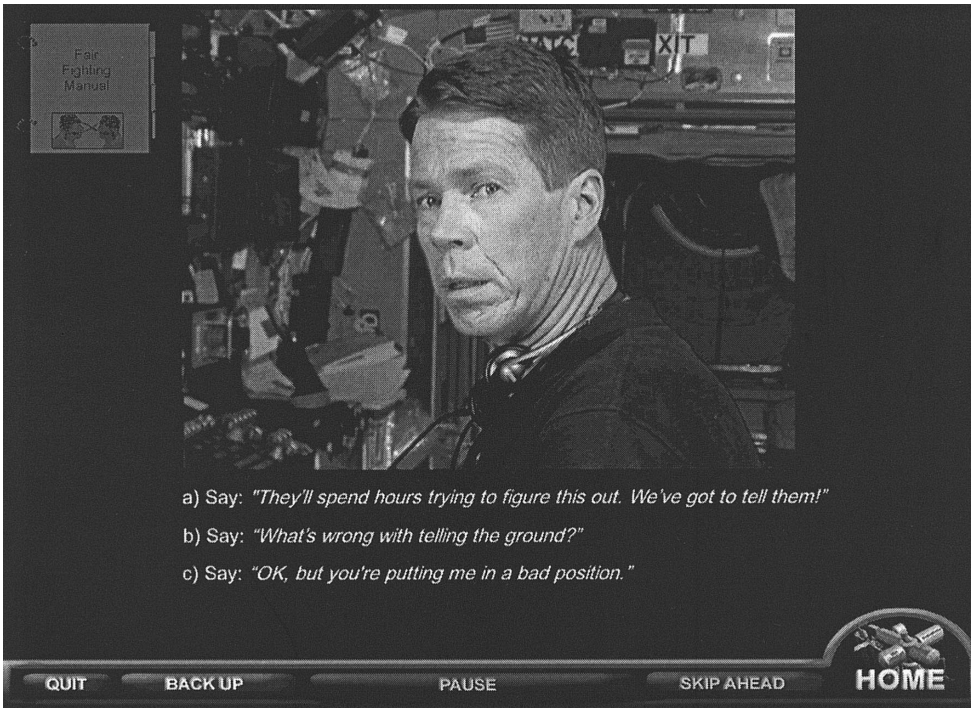

Fig. 3. Screen shot of a conflict management training simulation.

telling the ground. Users see the results of each choice played out on video, followed by coaching from Dr. Greenhalgh. They are encouraged to try out options that they would not ordinarily choose, since learning takes place along all routes through the simulation. Future conflict simulations will focus on silent (as yet unacknowledged) conflict, crew-ground conflict, and mediation training.

It may seem counterintuitive to teach a social skill such as conflict management via self-instruction. Much of conflict management, however, has to do with developing an awareness of one's automatic thoughts and emotional reactions in response to conflict, and learning how to manage these internal processes. Additionally, other interpersonal skills have been taught via self-instruction, such as conflict management for adolescents (6,7), employment interviewee skills (41), psychotherapy (5), counseling (13), and parenting (5).

Depression training in the Simulator module will also begin with a 10-min briefing that explains the etiology and symptoms of clinical (major) depression and how it differs from milder forms of depressed mood. The briefing will stress that it is most effective to monitor one's own emotional state and take appropriate actions at the first signs of depressed mood to help prevent it from escalating into depression. Simulations will teach users how to recognize depression in other crewmembers and assist them.

The Self-Assessment module will contain empirically validated, published measures of depression, interpersonal conflict, and general well-being. Others can easily be added in the future. When users enter the Self-Assessment module, they will be presented with a list of assessments that are available, as well as brief descriptions of each one. Users will be guided through a decision algorithm if they are uncertain about which assessment to take. Clicking on an assessment will bring up a multiple-choice measure, most of which will take 5 to 10 min to complete. Permissions are currently being obtained from publishers to incorporate these measures into the system.

Unlike most computerized psychological assessments, the system will provide feedback directly to the user, not to a health care provider. In keeping with the ethical principles of test administration (1), raw scores will generally not be provided; rather, qualitative feedback will be given, along with recommendations of other portions of the Virtual Space Station that may be helpful to them at that time (e.g., self-treatment of depression). Finally, users will be asked if they would like to save their results. All assessment data are encrypted and secure, and available only to the individual user.

Data security is a tradeoff. The benefit of keeping self-assessment data confidential is that this promotes candid answers and allows the crewmember to derive maximum value from the system. A dilemma could arise, however, if a user were to acknowledge suicidal or homicidal ideation or intent on an assessment. If any intent to harm is reported, the current design is for the system (through text plus audio and video of mentors) to strongly encourage the user to discuss these thoughts with others on board and/or with the ground. No automatic "alarm" system is planned for the system that would override users' privacy, although such a function could be incorporated if desired by the astronauts, flight surgeons, and Mission Operations. A question on this topic will be asked in the usability test.

The Interventions Module will contain self-help tools for current psychosocial problems. In order for the interventions to fit together coherently, a consistent theoretical framework will be used in all programs. Cognitive-behavioral theory has been well validated for the prevention and treatment of many psychological and interpersonal problems, including conflict (18,87) and depression (16,89). Therefore, all intervention and prevention strategies will be grounded in cognitive-behavioral theory.

A depression self-treatment tool will guide users through the steps of Problem-Solving Treatment (PST). PST is a brief, structured cognitive-behavioral therapy that has been designed and tested for both major and minor depression in primary care (27,61). Because minor depression is often a reaction to stresses in one's life (8), PST appears to be an ideal treatment for long-duration spaceflight.

PST involves seven steps: 1) clarification (i.e., listing problems clearly, concretely, and breaking large problems into smaller, more manageable parts); 2) establishing realistic and achievable goals for problem resolution; 3) generating a set of potential solutions to reach the goals; 4) evaluating the pros and cons of each solution and the impact each would have on the social system (i.e., other crewmembers); 5) selecting a preferred solution and making a concrete action plan; 6) implementing the preferred solution; and 7) evaluating the outcome, troubleshooting, and beginning the cycle again, as necessary. Although some problems may not be readily solvable, solving at least some of them can provide a sense of control, which helps to mitigate depression.

British investigators (14,62) have demonstrated that PST is more efficacious than "usual" primary care for depression and equal to antidepressant medication for patients with major depression. In studies by Hegel et al. (27) and others (3,62,63,88), acceptance of PST among consumers has been good, with very low dropout rates from treatment studies. A recent study by Unützer et al. (86) demonstrated that nurse practitioners with no prior mental health training can learn to deliver this brief intervention effectively and reliably. This study attempts to advance the implementation of PST by delivering it without a health care provider.

PST was chosen over other depression treatment approaches in part because it is more structured than other approaches, such as cognitive-behavioral therapy or interpersonal therapy. Because it is designed to be delivered in a sequence of clearly defined steps, adapting it to computer delivery requires less branching than other approaches. Additionally, even when PST is delivered live, patients are not provided with suggestions on how to solve problems or which problems to address. PST facilitators merely guide them through the process of creating and judging their own solutions and making their own plans. It is anticipated that a computer algorithm can be developed to accomplish the same task.

Through video and audio prompts, Dr. Hegel will guide users through the steps of PST. Computer-based PST will take the form of an interactive workbook for programmed (structured) writing (48) in which the computer asks users to type responses to questions. No computer program has been developed that can "understand" natural language well enough to provide counseling. Therefore, users will be guided to evaluate their own responses to computer queries in order to generate and implement solutions to reduce their depression.

In addition to depression self-treatment, the Interventions module will also contain an algorithm to help individuals engaged in ongoing conflicts identify ways of breaking the conflict cycle. Similar to the PST process, Dr. Greenhalgh (on video and audio) will ask users to type in responses to questions and help them evaluate their own responses to identify options for managing the conflict. Additional self-help tools can be added to the Interventions module as they are developed.

The Resources module contains an Advanced Training section, e-Library, and an Interviews area. Whereas the Simulator module contains basic training, the Advanced Training section of the Resources module enables users to gain more in-depth knowledge and skills in areas of interest to them. Advanced Training topics in conflict management will include mediation training, evaluating the meanings one assigns to others' behaviors, and managing negative emotions. Advanced Training in depression management will include an exploration of the neurobehavioral causes of depression, alternatives for treating depression, and strategies for preventing depression.

The e-Library within the Resources module contains electronic text and audio versions of books on topics covered in the Virtual Space Station. Motivational readings such as polar survival stories are also included. All books are presented in their entirety, and permissions are currently being obtained from publishers to include them. The e-Library dramatically and cost-effectively expands the amount and breadth of content in the system.

The Interviews section of the Resources module will contain video interviews of former long-duration flyers who provide advice on how to adjust to extended missions, and possibly interviews with individuals who have experience in analogous isolated environments. Media testimonials have been demonstrated to be an effective means of changing behavior and attitudes when the person giving the testimonial speaks from relevant and credible experience (46). In this case, the intent is to help crewmembers engage in psychosocially adaptive behaviors.

Finally, the Data module will provide access to all self-assessment and intervention data saved by the user, as well as a training checklist indicating which training the user has completed in the Virtual Space Station, a journal that astronauts can use to record their experiences, and a general notes section.

Development and Evaluation Process

Development of the system is occurring in five phases: 1) consultation interviews; 2) prototype production; 3) formative evaluation; 4) completion of the conflict management and depression programs; and 5) efficacy evaluation of the depression intervention. At the outset of the project, and continuing through production, 13 veteran long-duration NASA flyers were interviewed from the ISS, Mir, and Skylab programs. The goal of these interviews was to elicit input on the best and worst practices for managing conflict and depression on long-duration missions, as well as feedback on several potential training simulations. These interviews appear to be the first conducted to distill the best practices for managing psychosocial problems on long-duration spaceflights from the perspectives of veteran flyers. The interviews enabled content to be developed by combining deductive (top-down) input from clinical experts with inductive (bottom-up) input from veteran long-duration flyers, who are experts on extended missions and representative of the system's end users. The final product of the first phase was a content document that specifies the information and skills to be covered, and a design document, which specifies how they will be taught.

The second phase is to produce the prototype, which is currently underway. This phase involves writing scripts for mentors and actors, identifying interviewees to discuss their experiences on camera, designing and programming interactivity, videotaping training simulations, interviews, and mentor discussions, and securing permissions from publishers to include psychological assessments and copyrighted texts. Usability and design elements are tested as they are developed and integrated into the system. In order to address the broad spectrum of psychosocial challenges that may materialize, the most efficient approach is for multiple teams to develop content for the system simultaneously while maintaining a consistent design, look, and feel. The system's modular structure is intended to facilitate such collaborations.

The third phase involves conducting a formative evaluation of the system following an established protocol (22) to obtain feedback on the system's usability, acceptability, credibility, appeal (how captivating it is), and ways to improve it. This phase will be carried out at NASA-Johnson Space Center's Usability Testing and Analysis Facility and will involve at least 10 current members of the astronaut corps. Astronauts will be asked to complete questionnaires and brief post-use interviews. Some measures, such as the Computer System Usability Questionnaire (50), are normed and published, whereas others are developed specifically for this study. Although some measures will be multiple-choice, most will yield qualitative data, which are generally the most valuable in the formative evaluation stage.

In the fourth phase, modifications to the system will be made based on formative evaluation data, after which the remainder of the conflict and depression content will be completed.

The fifth phase is efficacy evaluation. Efficacy studies measure a clinical intervention's impact under controlled conditions (i.e., lab or research clinic), whereas effectiveness studies measure how they perform in real-world settings. One reason for testing efficacy before effectiveness is that if a clinical intervention fails to show acceptable potency under controlled conditions, it is unlikely to do better in real-world settings, in which many uncontrolled variables can interfere with its implementation. Moreover, to achieve sufficient statistical power to conclude whether a countermeasure for treating a clinical condition works, it must be evaluated on a large enough group of persons who have that condition. Finally, NASA requires that countermeasures be first tested on the ground with non-astronaut participants, then with analogue populations, and finally with astronauts (64). If the countermeasure demonstrates acceptable potency in an efficacy evaluation, the next step is to test its effectiveness in an analogue operational setting, such as an Antarctic winter-over expedition. Finally, if the countermeasure demonstrates effectiveness in an analogue environment, it will be ready for testing in space.

A randomized controlled efficacy trial of the depression self-treatment portion of the system is scheduled for 2007–2008. The trial will include 68 mild to moderately depressed persons in the Boston area who approximate the astronaut population in education (minimum of a Bachelor's degree), age (30 to 60 yr), and computer familiarity (computer use at least twice per week). Participants will be randomly assigned to computer-based treatment or a wait-list control group. It should be noted that wait-list controls have been used in similar PST evaluations (2,52), and resemble the actual situation on long-duration missions. An efficacy trial of the conflict management content is currently being planned. Results of the evaluations will be reported when they become available. The study protocol was approved by the Beth Israel Deaconess Medical Center Committee on Clinical Investigations, the Dartmouth College Institutional Review Board, and the NASA-Johnson Space Center Committee for the Protection of Human Subjects.

Evaluating the depression treatment with non-astronauts presents limitations. Long-duration crewmembers live and work in vastly different environments from urban professionals—or from persons from any analogue population. Additionally, they are carefully selected on the basis of their career achievement and physical and mental health. Therefore, they will likely be more accomplished, intelligent, and sophisticated than subjects in the efficacy trial. These differences do limit the generalizability of results from the evaluation to the astronaut population. On the other hand, PST has already been demonstrated to be effective for a wide range of populations, which included highly educated professionals (3,62,63,86), and there are neither empirical nor theoretical bases to suggest that it would be less effective for astronauts than for other populations. The question is whether PST can be adequately delivered via interactive multimedia. If professionals with a reasonable amount of computer experience find it usable and derive clinical benefits from it, we anticipate that astronauts are likely to benefit, as well.

DISCUSSION

The goals of countermeasures for behavioral issues are broader than those for medical problems. In most cases, the goal of a biomedical countermeasure is to restore physiological functioning to an optimal, preflight level, or to prevent problems from occurring in the first place. In contrast, the goal of behavioral countermeasures is not merely to maintain, but to improve functioning during the mission. Whereas it may be unrealistic to expect space crews to return to Earth even more physically healthy and fit than when they left, it is a reasonable goal that crews increase their cohesiveness and individuals become better adjusted to living in isolation. Indeed, several reports suggest that the challenges of long-duration spaceflights can be psychosocially salutary, making individuals more resourceful and resilient, and fostering personal growth (15,36,40). The system under development is intended to assist in this growth process, as well as to help prevent, detect, and ameliorate psychosocial problems.

Finally, the potential benefits of this system extend beyond space exploration. Clearly, the system, if effective, could be adapted for use in other isolated operational environments such as polar research stations, submarines, commercial ships, oil rigs, and underwater research bases. Furthermore, even greater value could be derived by making similar psychosocial support systems available to the public in settings such as primary care practices, public and mental health centers, schools, social services offices, places of worship, military bases, prisons, and eventually at home or in any location, through broadband Internet.

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