Maintaining Psycho-Social Health on the Way to Mars and Back

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ABSTRACT

In future long duration Mars exploration missions, network limitations and the lack of real-time communication capabilities will impact various aspects of space crew performance as well as behavioral health. Studies in ground-based analogs of Isolated and Confined Environments (ICE) such as Antarctica have identified sensory and social monotony as threats to crew psychological well-being. Given the importance of behavioral health to mission success and the extreme conditions of space travel, new methods of maintaining psycho-social health and social connections to support systems are critical. We describe ANSIBLE – A Network of Social Interactions for Bilateral Life Enhancement. ANSIBLE leverages Virtual Environments (VEs) to deliver evidence based wellness promoting strategies and socially intelligent Virtual Agents (VAs) as tools to facilitate asynchronous human-human communication, and counteract behavioral health challenges associated with prolonged isolation and deep space exploration.

Categories and Subject Descriptors

H.5.1 [**Multimedia Information Systems**]: Artificial, augmented, and virtual realities.

General Terms

Measurement, Design, Experimentation, Human Factors

Keywords

Virtual Worlds, Virtual Agents, Psychological support, Communications, Psychological Health

1. INTRODUCTION

Currently thousands of individuals all over the world are socializing, conducting commerce, collaborating, and essentially living their lives in a physically isolated environment, but are psych-socially engaged through virtual environments. In virtual worlds, individuals may find the satisfaction they seek in real life [1]. We speculate that virtual experiences can maintain and enhance social connections and interpersonal skills in real life, and physical environmental stressors can be alleviated through strategically designed experiences delivered through virtual environments. Virtual Environments (VEs) and their predecessor, Virtual Reality (VR), has been used to train technical skills that result in real life performance enhancements. With the advent of Virtual Worlds such as Second Life, Habbo, Poptropica, Club Penguin, etc., the power of social communities are driving continued use of virtual worlds for both work and play. For example, the annual OpenSimulator Community Conference brings together thousands of researchers and industry experts in a venue that looks, feels, and produces some of the same results as traditional conference meetings, but without the need to travel.

Loosening the requirement to be physically present can translate to advantages, especially for those individuals who are very, very far away. Mars astronauts will travel at least 54 million kilometers one way to the planet surface. This translates to communication delays that will impact both mission related communications, as well as how crew members connect with their family, friends, and psychological support system. Coupled with the long duration of the mission (approximately three years), persistent stress, lack of sensory variety, and social monotony, these threats to behavioral health are recognized as serious risks to mission success. Effects of social and sensory monotony have already been observed aboard space crafts [2,3,4,5]. NASA began investigating the effects of confinement, monotony, and prolonged close contact with other crew members [6] when three astronauts took a Sunday off from scheduled work during an 84-day long Skylab mission in 1974. Observations of subjects were also made in Antarctic, where individuals spent seven to nine months isolated by the severe winter weather. Studies of Antartic winter-over subjects showed that although individuals survived the winter, they exhibited severe drops in productivity, high levels of anxiety and hostility, and risk-taking and rule-breaking behavior, including fistfights and hazing unpopular members of the group. In our own studies of human subjects isolated in a four month exploration analog mission, anecdotes from subjects suggest some individuals experienced heightened sensitivities to minor social conflicts, changes in perception of time, increased ruminations on negative experiences, and changes in the perception of physical environment. Prisoners in solitary confinement have also been observed for the effects of social and sensory monotony [7,8]. To understand how prisoners responded to months or years-long solitary confinement, researchers conducted case studies in prisons themselves, and use prisoners' personal accounts collected by mental health and correctional staff [9]. Research has also been conducted more broadly on the effects of sensory deprivation and monotony, including neurophysiological and psychopharmacological approaches [10] and changes in perceptual function [11]. The social monotony and isolation of a long duration mission can result in limited perspective taking, increasing ruminations and likelihood for misunderstandings. Maintaining and strengthening of social skills are crucial to counteract the risk for deterioration after extended periods of isolated activity. The astronaut in-flight needs the appropriate outlet and support system in place, such as to allow for the possibility to engage in social activities and to withdraw into a more private sphere on a routine basis. The solution must maintain ties with existing friends and family, but may also

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accommodate developing new ties with new friends and colleagues as suggested by prior research [12].

We believe the behavioral health threats of social and sensory monotony will be amplified by the lack of real time communications. The network latency that will exist between Earth and Space currently occurs between individuals on Earth, where geographically distributed groups want to live or work together remotely. Both real time solutions such as video, voice, and text chat, and time delayed solutions such as email, social network websites, and micro voice messaging serve to keep communities connected, but they lack the geospatial information afforded by physical worlds.

In the past decade VEs and intelligent Virtual Agents (VAs) have come together to make possible a new range of human interaction opportunities. Virtual Worlds (VWs) have taken the paradigm of Virtual Reality and transformed it into rich, persistent, networked 3D spaces populated by tens of thousands of people using embodied avatars. Intelligent VAs are able to work as tutors, guides, conversational partners, and even as virtual therapists [13]. VWs combined with VAs have been used by ourselves and others to address human interactions in a diverse set of domains, from language and culture training [14, 15] to medical consulting [16, 17]. Morie et al. used VWs as an advanced form of tele-health care to facilitate and support soldiers in reintegration into civilian life in a project called "coming home" [18]. The authors have been developing a socio-linguistics based engine for driving intelligent VA social behavior and for detecting emotional changes in humans through their speech or written word. VEs have demonstrated their utility in enhancing telemedicine [19,20 ,21 ,22, 23] supporting behavioral therapy [e.g. 24], and applications in language and culture training [25,26], as well as robotics and equipment maintenance training [27, 28]. We believe its promise can extend to enhancing psychosocial health in space flight to directly address the risk of adverse behavioral conditions. We describe our process and results below.

2. REAL LIFE MIRRORING VIRTUAL LIFE

There is increasing evidence that behaviors learned in VWs can migrate into the real world. For example, in a meta-study of the field of Virtual Reality Exposure Therapy (VRET), Parsons and Rizzo [29] note the efficacy of VRET in treating various anxiety disorders, such as acrophobia, agoraphobia, social anxiety and post-traumatic stress disorder. More directly, Yee and Balienson describe "The Proteus effect" [30, 31], the observed phenomenon where self-perception and skills obtained through a digital persona (i.e. through manipulations of their online avatar), including attitudes gained from virtual worlds, are maintained even when the human reenters the real world. All of this advocates that humans not only interact socially and meaningfully in VEs, they can also be primed for behavior modification and interpersonal sensitivities, and the effects of that priming can carry over into their offline interactions in live situations.

The ability to harness benefits acquired from virtual spaces translates to several applications in space. Psychological support can play an important role in risk mitigation since astronauts may experience anxieties while in flight, which then could be alleviated (or even prevented) by in vivo virtual world intervention. Given the limitations of the habitat, VEs may also be used to encourage relaxation and mindfulness: to create a spot to gather one's thoughts, to calm down, or to be alone in a manner that facilitates a restful state in the person. For instance, an astronaut may choose to sit in the VW near a quiet spot designed for meditation, or practice mindfulness therapy (as developed by John Kabat-Zinn [32]) utilizing awareness of the present moment and centering of one's thoughts. One of the authors have studied these methods deployed in Second Life [33]. Such quiet activities could help in providing support to people of different personality types, whereby some people gain energy by socializing (extroverted people) and others (introverted people) gain energy by isolating and recuperating alone. A tonic environment may be, for instance, a waterfall in a forest, or a mountaintop on a snow-filled valley. VEs may thus also provide a way to relax, recover and gather one's thoughts by a feeling of quiet and connection through one's environment. For many, this is an important way to "ground" oneself, even though one's physical environment is stressful, disengaging with that environment and changing it to a relaxed environment is crucial.

VWs may also provide good environments to acclimatize and acculturate crews that have been long removed from the world as a form of re-entry preparation. They can do this by providing them with updates on world events, news, new movies and cultural and historical development throughout the mission. As these long duration missions keep them out of the loop, we see a great benefit in helping astronauts get additional information through VEs that help them acclimate to the changes they have not witnessed or experienced while away from earth.

3. REAL WORLD SOCIAL INTELLIGENCE IN VIRTUAL WORLDS

Artificial characters with human intelligence and social graces are still closer to science fiction then software reality. However, believable VAs that operation within well defined boundaries are emerging as possibilities today. SIFT has been developing a socio-linguistics based engine for driving intelligent VA's social behavior and for non-intrusively detecting emotional changes in humans through their speech or written word. Aside from the restriction of asynchronous communication and thus the use of VAs for real time interactions, there are additional benefits of using embedded Artificial Intelligence (AI) virtual agents enable precise, controlled scenario rehearsals that target specific objectives such as assessing emotional state. These include the simplest form: autonomous "bots" that serve as background characters or "non-player characters" (NPCs) in game parlance. Current video games use AI agents to provide conversation, challenges and background information to players. At higher levels, intelligent virtual humans can function as intellectual companions, cultural emissaries, competitors in game play, and resources for information. They can perform roles as health experts [34], pedagogical agents [35], guides to activities, troubleshooting experts, and as virtual friends. In traversing a virtual world, a person may encounter a virtual human and ask them questions about the environment, get provided with a game challenge, or simply have a conversation.

Embodied conversational agents [36] can converse with a person, and are programmed with information about a particular domain of knowledge. Using speech recognition, they can semantically infer what a person is saying, and provide an answer that pertains to the person's inquiry. Some recent examples in this area include learning bilateral negotiation strategies [37], for training therapists to deal with difficult teenage patients [38], physical ailments [39] and serving as guides to museum spaces [40].

Through natural-language processing, these agents can process what a person is asking, and by accessing a domain-specific database, provide an appropriate answer. The developments in this area are promising, in that such "virtual humans" can serve a variety of purposes, from background extras to give culturally oriented space richness, to game bots or challengers, or even as pedagogical agents for learning.

However, human communication entails the body and the mind, i.e. verbal and non-verbal language. The current state of the art embodied virtual agents tend to follow highly scripted behaviors, lacking the richness and flexibility of human behavior, as well as the ability to respond when a human performs actions not anticipated by their software developers. In the context of providing meaningful socialization, embodied VAs must move beyond their current limitations to include the idiosyncrasies of human behavior. Therefore, communicative realism has to match visual appearance (movement, posture, emotional expressions, gaze, etc.) with communicated content. SIFT has been at the forefront of developing and applying a theoretically based socio-linguistic model to increase the social intelligence of virtual agents. This model allows virtual agents to detect and exhibit interaction appropriateness in language, body gesture, and compliance behaviors across different cultures. Our designs which are based on theories from psychology, and have generated machine behaviors that are considered 'believably human' [41], opening the doors for humans to interact with machines through socially compelling and fulfilling ways. Below we describe the theoretical basis of this work.

Through over a decade of field study, sociolinguists Brown and Levinson [42] studied language use across 5 different cultures. They observed that people universally and across scenarios regularly deviated from efficient language use [43] by introducing added verbiage that they characterize as various levels of politeness. Brown and Levinson propose that this extra verbiage acts as a redressive strategy to mitigate face threat [44], that is, an imposition that the speaker poses to the hearer. Brown and Levinson believes the degree of face threat of an action is the sum of 1. the social distance between interlocutors, 2. the power difference between interlocutors, and 3. The imposition of the raw act itself. As an example, the imposition of asking someone for $5 is less than the imposition of asking someone for $500. Brown and Levinson claim that the degree of face threat posed by an act must be balanced by the value of the politeness behaviors used if the social status quo is to be maintained. We have, under various sources of funding, implemented the Brown and Levinson model to create computationally tractable and scalable quantitative politeness reasoners. This work has resulted in a content coding scheme, a software architecture, and set of algorithms that we call the Etiquette Engine™. The Etiquette Engine takes into account influences at the individual and cultural levels to calculate how an action may be interpreted in terms of politeness, and therefore whether it follows the cultural code of conduct. It would be trivial to craft agent behaviors that are consistently rude or overly polite, but most communication strategies occur in the dynamic believable middle ground, e.g. being assertive without being rude or being polite without appearing subservient. This is the danger zone where many social misunderstandings and threats to team cohesion can occur, and is the area of focus for the Etiquette Engine. We have validated the predictions of this mechanism with both trained and untrained raters—achieving a Robinson's A correlation of 0.931 among 3 trained raters in one experiment, well above traditional consistency thresholds of 0.7-0.8 for multiple-judge rating correlations[15].

In validating our model, we found that subjects perceived levels of politeness as designed, even when utterances came from machines in text format with no physical embodiment, age, gender or cultural cues, and voice synthesis thus no intonation cues. This suggests that a computational model was powerful enough to manipulate and predict perceived politeness. Further, subjects readily anthropomorphized machines, even when interactions were limited to text, confirming Nass's findings that humans generalize patterns of conduct and expectations for human-human interaction to human-computer interaction [51]. This framework adds realism and social intelligence to VAs by providing a model of nuanced human conduct. The framework can also be used to evaluate human behavior, as well as educate humans to recognize and reason about deviations in expected behavior. Consider the case of testing a negotiation strategy with a "virtual" crew member, where a display may show the VA's calculations of the situational context (e.g. high social distance coupled with a high imposition tasks causes the virtual agent to use more polite language towards the human). The human trainee can immediately see the virtual agent's justification for the politeness language. If the virtual agent's behavior was unexpected, the human can then reason about its actions (e.g. the virtual agent's perception of social distance between itself and the user is higher than that of the human's, or its perception of the imposition of the task is higher than that of the human's). This ability to "look under the hood" at an actor's perspective can be useful to identifying possible sources of social misunderstanding that can corrode team cohesion.

4. METHOD

We describe ANSIBLE - A Network of Social Interactions for Bilateral Life Enhancement, a communication and social support toolset which enables multi-faceted human-human and human-virtual agent interactions designed to accommodate technical and environmental limitations of long duration space flight. Our goal is to provide a holistic, evidence-based approach for formulating natural scenarios that address crew and Earth psychosocial health while ensuring its compatibility with currently known operational limitations such as bandwidth, communication delay as well as habitat restrictions. To design this system, we first leveraged a prior review of over 50 publications and technical reports to extract possible psycho-social dimensions of interest [45]. Using this literature review, we focused on psychosocial dimensions relevant to long duration exploration missions that can be addressed by virtual environments. We then conducted a review of current evidence-based best practices in supporting the psycho-social dimensions of interest identified above. In addition, we investigated methods of augmenting time delayed communication in VEs through VAs powered by Artificial Intelligence (AI) engines. In the last decade, researchers have begun focusing efforts on the merger of VEs and AI agents. A full survey of this work can be found in Morie, et al.'s survey on Embodied Conversational Agents (ECAs)[46]. The work of incorporating VAs into VEs is very much in its infancy, even more so than incorporating autonomous intelligent robots into the real world. Compared to other research into AI agents, the empirical data specific to VA effectiveness in either realism or helpfulness is limited. There are a few exceptions to this, however. For example, Jan D., et al. [47] note that virtual AI helpers are asked more questions than one might expect, while Weitnauer, et al. observed that when virtual world participants were unaware that they were conversing with an AI agent (named Max), they reported frustration with its repetitiveness [48], which paralleled reports about ELIZA, a simple natural language processor built in the mid-1960s which posed as a Rogerian psychotherapist[49]. Our own prior work showed that human subjects readily anthropomorphized even non-embodied agents [50], confirming Nass's findings that humans generalize patterns of conduct and expectations for human-human interaction to human-computer interaction [51]. Further, we found the social aspects of human-machine interaction affected not only subjective measures such as trust, but also objective performance metrics such as compliance [50]. More generally, we believe embodied VA will only amplify the human tendency to anthropomorphize technology, and increase the psychological investment and engagement of the human.

This work resulted in a list of broad and wide ranging strategies such as the use of plant life to combat monotony and sensory deprivation, training for marriage and family specific as well as general interpersonal skills, recalling moments of gratitude, and focusing on past and future responsibilities and expectations to reinforce sense of meaningfulness. These strategies can be implemented in a variety ways as VE realizations, ranging from novel virtual scenarios that families can experience together to the use of VAs to add social diversity and deliver training. Next, we selected a subset of strategies, reviewed commercially available VW technologies, and began to design activities surrounding those strategies within a virtual space. We describe the result of our designs below.

5. VIRTUAL ENVIRONMENT IMPLEMENTATION

We created a virtual space in which to implement the evidence based strategies that promote social connectedness and individual psychological well-being. The strategies we selected can be categorized as having the following objectives:

- Enhance human-human asynchronous communications
- Counter social monotony and isolation
- Combat sensory deprivation due to habitat and vehicle limitations

The resulting virtual environment consists of extensive outdoor spaces. The lighting and weather in the virtual environment can mimic those on Earth, providing the end user with reminders of the changing seasons and providing visual and audio stimuli otherwise not available. Currently on the International Space Station, the flight crew has a constant and majestic view of Earth. However, Earth will be a distant dot of light during some phases of a long duration mission. This can further increase the feeling of isolation and disconnectedness. Visuals as well as audio of nature sounds such as rain and wildlife will help to combat sensory deprivation. Looking at nature for even brief periods of time has been shown to decrease stress. There are many opportunities for virtual world implementation to leverage the positive effects of nature on psychological well-being [52]. Activities can be solitary, such as watching the sunrise/sunset and the movement of clouds, or they can be layered with social activities such as enjoying a camp fire.

In addition to outdoor spaces, we created a variety of interior settings within FAMCOM. These include spaces for large groups, such as conference areas for conducting asynchronous educational outreach events, as well as gathering places for small groups where individuals can engage in activities such as an asynchronous game of chess with a friend on Earth. Within the virtual space, end users can create and exchange virtual "care packages". This not only provides novelty to combat monotony, but gift giving boosts mood [53] and increases social connection to giver [54].

Flight crews and Earth-bound family and friends will not be able to interact in real time in the virtual environment. However, avatars that represent individuals can be automated and logged in to perform pre-recorded and even interactive behaviors. This activity of watching avatars in the virtual space is similar to watching a movie or a home video but with increased interactivity. Recently, the fields of neuroscience and film studies have come together in "neurocinematics". One area of interest is the role of "mirror neurons" and the effects of film watching on the viewer's emotions [55]. We believe this also applies in our application, where mirror neurons can be activated when viewing one's avatar interacting with objects and other individuals in the virtual space, causing real emotional responses. This idea is compatible with observations from both the "The Proteus effect" [30, 31], and "The Media Equation" [51], and is reported anecdotally by thousands of virtual environment users.

6. FUTURE WORK

The next phase of this work includes a ground based validation study to investigate the effects of performing health promoting activities within the deigned virtual spaces. We are currently collecting control group survey data in a Mars surface simulation mission where a crew of six will be isolated for 8 months. We will then deploy the ANSIBLE system in the following mission, where a different crew of six will inhabit the simulation facility for twelve months.

The specific application of supporting space exploration has a highly limited intended audience, but the ideas developed within this project can be applied to any groups for asynchronous communication, whether they are geographically distributed or not. The tremendous growth of asynchronous communication (e.g. IM, texting, email) shows that at least sometimes, the benefit of convenience outweighs the cost of coordinating with multiple parties for real time communication. While VEs are not meant to replace existing methods with which people connect, they can provide additional value. In the real world, interactions with people often go hand-in-hand with interactions with tangible things. VEs can unleash new dimensions of interaction that allows for shared manipulation of objects and shared experiences, potentially enhancing shared mental models and improving cohesion and coordination.

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