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Martian Delight: Exploring Qualitative Contact for Decoupled Communications

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Abstract

Exploring farther into our solar system for planetary exploration will require the human crews to reside in their space transfer habitats for a long period of time. These explorers will also face isolation, owing to the sheer physical distance from the Earth, which may eventually affect their health and well-being. Furthermore, looking at a trip to Mars, astronauts will have to wait for at least forty minutes to receive updated round communications from Earth, due to the time it takes for the signal to travel the separation distance at the speed of light. Thus, when it comes to long-duration crewed space missions, communication and the feeling of connection with their loved ones—friends and family—on Earth is crucial for the astronauts' well-being. In this context, exploring a new communication approach for long-duration spaceflight seems necessary for our missions to Mars. This paper attempts to introduce a new way of decoupled communication that enables astronauts to connect with their feelings towards their loved ones on Earth via embedded interactions, focusing on the idea of "qualitative contact". The idea of qualitative contact was inspired by one of our previous studies on the concept of "qualitative interface" in relation to HCI (Human-Computer Interaction), then extended to our case study for human-object interactions. Much of how we construct meaning in the real world tends to be qualitative rather than quantitative. Yet quantification has become a default method for displaying, presenting and communicating information. In this paper, we explore beyond the idea of ordinary distance communication and information exchange during deep space exploration. We introduce how human explorers in a space transfer habitat can qualitatively contact their loved ones on Earth during their long-duration space missions. We discuss our design processes, which includes the study of human-centredness, communication barriers, the ideation process, and prototype development with a boundary-object based demonstration. We believe that our communication method or tool could stimulate ideas for space habitat designs beyond today's technological solutions for long-duration and long-distance space missions. By advancing the astronauts' physiological and psychological well-being, human explorers could venture to expand our civilization deeper into the solar system. What are the ways to make astronauts feel connected with their family and friends back on Earth during their long-duration space missions? Here we share the idea of qualitative contact through a device we call Martian Delight—a device intended to advance the astronauts' well-being.

Keywords: Deep Space Missions, Communication System, Interaction Design, Human Spaceflight, Space Habitat, Experience Design

1. Introduction

Space agencies from around the globe are looking beyond the International Space Station (ISS) for the future of deep space exploration. To explore beyond the ISS and push humanity farther into the solar system, human explorers need to travel and reside in their space habitats for a long period of time. According to NASA's Mars Design Reference Mission Architecture 5.0—see [1] Addendum #2—a round-trip to our planetary neighbor would take about 1000 days with a crew of 6. If we consider this in terms of the average human life expectancy, a single round-trip can take about 1/30 of an astronauts' lifespan, and even more if they stay on the Martian surface longer. This research attempts to value and improve the astronauts' well-being during their long-duration deep space mission to Mars. Particularly, we are focusing on overcoming the psychological barrier of delayed communications and resulting feelings shared between astronauts and their loved ones on Earth, during their long-term separations.

Looking at a trip to Mars, astronauts may need to wait for as long as forty minutes before receiving updated round communications from Earth, due to the time it takes for the signal to travel the separation distance at the speed of light. In this context, utilizing the speed of light may not always be the most preferred communication method for astronauts interacting and connecting with their loved ones on Earth. Hence, exploring the possibility of a new communication method or tool for long-duration spaceflight seems intriguing, when developed in support of the astronauts' long-term well-being. Considering that today's technology-driven human space exploration paradigm does not comprehensively embrace approaches beyond the basic physiological and psychological needs of the astronauts [2], we believe that our focus on qualitative communication can push the boundary of space-related innovations in relation to human-centeredness.

In this paper—as a follow on to [3][4][5][6]—we explore the idea of qualitative contact via decoupled interactions through a boundary-object based artefact, that enables astronauts to interact differently with their loved ones on Earth, during interplanetary spaceflight. The idea of qualitative contact was inspired by the concept of qualitative interface [4] in terms of understanding the relationship between humans and qualities of phenomena. Fig. 1 shows an example of how a qualitative interface may work in the context of a person experiencing weight or force [7]. Here, the shape of a liquid, pressure, expansion, and the constant change of scale provide an intuitive experiential value of weight or force beyond merely providing a numerical value on a scale. These qualitative representations may improve people's understanding and experience about the relationships between meanings and phenomena. It provides a direct experiential feedback loop that—through a perceptual cycle [8]—shapes their cognitive model about the interactions and responses.

Here we introduce a tool that decouples communication from the distance that information must traverse at the speed of light. By doing so, astronauts are able to communicate with their loved ones on Earth, through qualitative contacts. It is achieved by introducing a time delay into the interactions between the astronaut and the artifact in space, and the same artifact and the loved one on Earth at an earlier time. These contacts are expected to support the well-being of the crew, which could be an essential ingredient to successful long-distance space missions in the future.

2. Communication and Interaction Barriers

Considering that the crew on a long duration space mission to our planetary neighbor will be relatively small, it is imperative to focus on the astronauts' qualitative experiences to ensure their well-being. This needs to complement the support for their basic physiological and psychological needs in Maslow's Hierarchy of Needs [9][10][3]. Addressing higher level needs is expected to have a positive influence of crew health, and could reduce performance related risks for the mission. Especially, when the astronauts travel to explore Mars for the first time, isolated perceptions can become a serious issue for them. A retired NASA astronaut, Nicole Stott, once said: "*nothing beats that first hug after landing*" after returning to Earth from the ISS [11]. It should be noted that a trip to the ISS is incomparably shorter than that to Mars. As such, improving the feeling of connection and focusing

Fig. 1: The sealed liquid between the two glass sheets immediately expands its surface according to the pressure it receives on the glass surface.

on human factors could be crucial for the future of deep-space exploration [3].

There have been ongoing efforts to explore optical laser communication technology to improve data transfers for high data volume communications on future deep-space missions [12]. Nevertheless, these communication systems are limited by the speed of light, thus these communications still would not be instantaneous. In this context, we need to find alternative ways and think beyond technological solutions to confront this type of communication barrier, and to push the boundaries of future deep-space communications.

Fig. 2: Astronaut Bob Behnken pushing a floating toy dinosaur around the cabin of the Crew Dragon capsule, as it reaches low-Earth orbit in May, 2020.

In this paper, we challenge this practice by exploring the idea of qualitative contact and decoupled interactions to enhance crew interactions in support of their psychological well-being.

3. Qualitative Contact & Decoupled Interaction

Here we consider qualitative contact as a human-interaction method that enables people to experience a feeling of connections with their loved ones through qualities of physical phenomena in the context of distance communication. Qualities of physical phenomena mean phenomena involving physical properties of a matter—physically visible in front of the naked eye—that embed certain meanings or values. For example, Fig. 2 shows astronaut Bob Behnken with his son's dinosaur toy which is floating around the cabin of the Crew Dragon capsule. Here, Bob wants his son to be excited at seeing his toy floating around the cabin. In this context, the dinosaur conveys and embeds certain meanings, and functions as a communication channel between the two people. Through this example we can learn that the feeling of connection is not something we can only achieve via instantaneous communication or information exchange, but also through a certain decoupled interaction.

In our research, we contemplate decoupled interaction as a communication system where a person can experience the other person, without being connected or simultaneously coupled spatially and temporally. We attempt to use qualitative contact and decoupled interactions as methods or approaches to explore opportunities for a deep-space communication system between users. These approaches were inspired by our early research and provocation on cognitive playfulness in Fig. 3 [5]—where cognitive playfulness includes playing with thinking, knowing, believing, expecting, rationalizing, and other such cognitive processes—and a spectrum of qualitative displays [4] in terms of understanding how people shape their individual experience through qualities of phenomena. These ideas and thoughts were then associated with the question of how we might address higher-level astronaut needs on long-duration spaceflight, through an interface that provides an emotional connection and bridge between the space travellers and their home [3].

4. Constructivism & Phenomenology

Much of how an individual constructs meanings and experiences in the real world tends to be qualitative rather than quantitative. We behave, act, respond and dialogue with qualities of phenomena and understand relationships between them. Is John smarter than Steven? Will she accept my apologies? Is he going to be late again? Do we have a bathroom in that building? [4] This research considers constructivism [13] and phenomenology [14] as useful approaches/lenses or mindset for understanding how individuals construct their thoughts and experiences to make sense of their world. Constructivism—specifically radical constructivism [15][16]—maintains that people construct their understanding and knowledge of the world we live in through their own experiences. Each of us generates our own mental models, which we use to make sense of our experiences. Thus, there is no definite reality to be found that is independent of all experience. This may sound to be a profound statement, yet we can argue that the world as we know it is perceived by someone, and thus we all view the world through our experiences. According to Wittgenstein [17], "*the limits of my language means the limits of my world*". We could adopt this to a constructivist view, stating that "*the limits of my experiences means the limits of my world*".

The domain of phenomenology is all about human experiences; it explores structures of conscious experiences. Phenomenology studies how phenomena and things (e.g., people, objects and events around us) appear in our experience from a first-person point of view. It also includes the reflections and conversations of our own conscious experiences, as we experience them. Experience here embraces not just passive experiences, such as smelling or hearing, but also active experiences, as in walking, bleeding or staring [18][14][19].

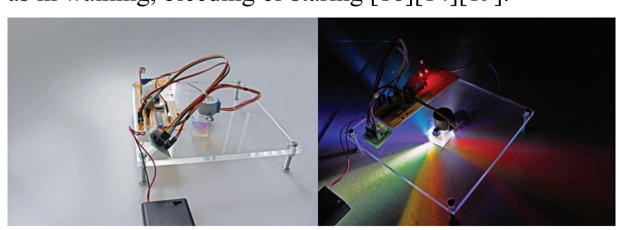

Fig.3: This unusual machine or experiment is a stationary device (left) that appears to do nothing. However, when there are no humans in its environment—detected by no sound, no motion and no light—it secretly starts to emit beams and rays of stunning colors/lights by rotating a prism, which no human can ever see (right). Although it practically provides no interaction, our pilot study suggests such a decoupled phenomenon could produce a certain joyful perception through cognitive/perceptual cycle [5].

This research considers both constructivism and phenomenology as useful approaches / tools / methods to investigate qualitative aspects of human experiences. We value all sources of the human experience. In this use case we apply it to the imagination of the astronauts to enhance their well-being. For instance, we have explored the possibility of stimulating the limbic brain through the sensory systems (including touch, olfaction, hearing, vision, and taste) to reduce the crews' stress, while discussing the possibility of using form, function, an interactive lighting system, smell and materiality to question what might bring comfort to astronauts [3][6].

We believe that addressing caring through qualitative aspects of individual crew members can greatly improve and inspire the future of deep space exploration. It might be especially relevant in the near term, with a small crew onboard an interplanetary long-duration space mission. Our approach is to focus on communication systems in the context of memory associations, employing the idea of qualitative contact and decoupled interaction, while valuing constructivism and phenomenology to appreciate human experiences.

5. Project: Martian Delight

Project Martian Delight (Fig. 4) is a communication system that enables an astronaut to qualitatively contact their loved ones on Earth through decoupled communications during deep space exploration missions. The constructed prototype is a proof of concept that enables the qualitative contact via a reward system [21] by locating a hidden reward within the device, namely, inside a red egg. Within the device, there is a tangible gift or surprise from an astronaut's family or friends on Earth. Nevertheless, the egg is locked and can be opened only if the owner of this egg—the astronaut—completes their tasks during their long-duration space mission. These tasks may vary, and typically related to the astronauts' psychological or physical exercise and well-being. For example, an astronaut would require to exercise consistently for 2 hours every day for a month in order to unlock their allocated egg/reward, or they have to consume healthy foods to maintain their health for a certain period of time. The device would receive a signal once the owner completes their tasks. Once the device receives this signal—the current prototype is receiving a light source as an example input signal, but this source can vary depending on the context—the egg/reward will follow the track and fly out from the transparent container, propelled by airflow (or "wind") produced by an actuator within the microgravity environment (Fig. 5). While the reward system encourages crews to actively engage and keep their healthy daily activities through a progression, it also provides a sense of accomplishment/ delight once they unlock the egg. In turn, this is expected to result in psychological and physiological support towards the astronaut's well-being [21][22]. The reward would be usually a meaningful or memorable physical item that connects the feeling of both parties—family and astronaut.

Although the current prototype can only contain one physical item—one task—per device, our final device is aiming to contain about 20 different physical items/ rewards per device. Considering a mission to Mars would take about 1000 days [1], one single reward in a device is insufficient. Instead of one single reward, multiple rewards can motivate astronauts to look forward to their

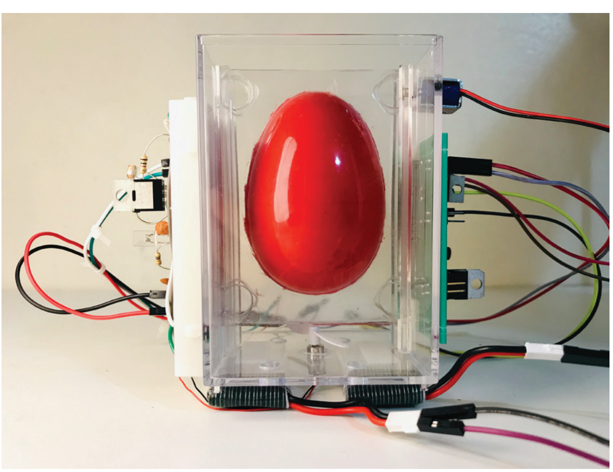

Fig.4: Project: Martian Delight—the device is holding an egg/reward on standby mode. It launches/releases a reward once the owner completes a task.

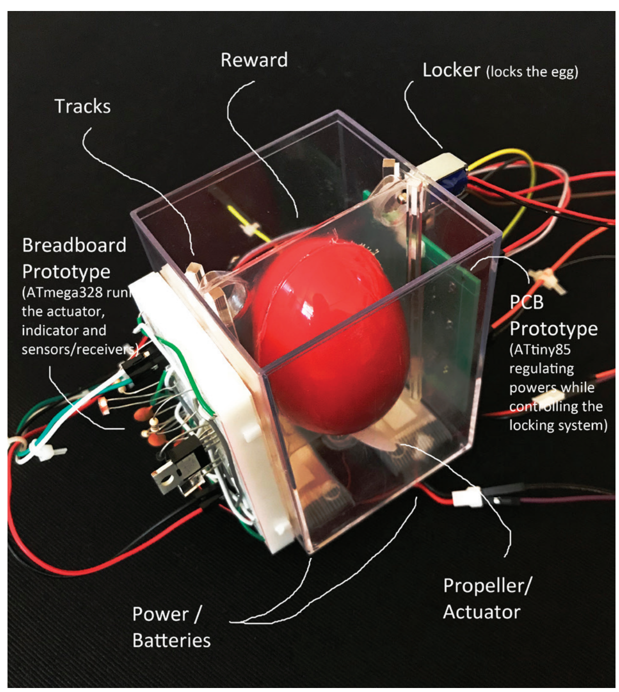

Fig.5: Project: Martian Delight—detailing components of the early prototype (Version-A)

Fig.6: Embedded nature of multiple "surprising" objects can be illustrated through the design of Matryoshka dolls, which are a set of wooden dolls with decreasing sizes, placed one inside another.

subsequent surprises from their loved ones over the course of their journey. This would support the crew's well-being by improving the feeling of connection, and therefore contribute to a successful long-distance/duration space mission. In the meantime, family or friends on Earth may also imagine their family/friend—the astronaut—being able to take care of their well-being, while they are isolated on their deep space mission.

For this nested object approach we were originally inspired by the Matryoshka dolls (Fig. 6)—a set of wooden dolls of decreasing sizes, placed one inside another—in terms of how it may delightfully surprise people. In future prototypes and working towards a final design, we are planning to employ this type of nested format to minimize the size of multiple rewards to fit into a single device. However, the sizes of physical rewards might be different; therefore, we have to reconsider practicality of such an idea. We are considering using a vacuuming method, an olfactory interaction method, a hand-written text method, and many others approaches to shrink the sizes of rewards for our next prototype.

5. Discussion and Future Research Plans

6.1 User study & COVID-19

Since the prototype device is designed for microgravity environments, it is rather difficult to test its full functionality including user testing on Earth. In addition, meeting astronauts for user testing is practically difficult, therefore alternative approaches should be considered.

While our device needs a microgravity environment to enable the egg/reward to float/launch out from the container, we do not need a microgravity environment for testing the performance of our reward system itself.

To test the reward system, we would first need a person who is in an isolated environment. Currently, COVID-19 is shaping the Earth into such an environment, and we believe this rather unfortunate situation can be a potentially useful circumstance for testing the prototypes and their operations on Earth. Although we have not discussed any of the details yet about how we could leverage the COVID-19 situation as a tool for testing, we consider using such an isolated situation as an alternative way of testing the performance of our qualitative communication system in our future studies. We believe that receiving and incorporating the findings from user feedback would be essential for improving our decoupled communication systems/prototype, because the system exists to induce and understand positive human experience and interactions through physical phenomena.

6.2 Precision of communication

While the decoupled communication system could provide a feeling of connection by using a physical artifact as a perceptual channel, there is a lack of precision in terms of what information and experience has been shared through this physical artifact. Although this is not a crucial factor in this qualitative communication system, finding a way to measure its impact and effectiveness could be useful for better understanding the experiences of the crew. In this context, we believe that understanding human experiences through the lens of both qualitative and quantitative approaches could improve our communication system in the future.

6.3 Other forms of qualitative contact

Although the current focus is on physical artifacts in relation to the idea of qualitative contact and reward system, in our future research we would consider which alternative item forms or methods could be carried inside our device/egg. For instance, olfactory interaction can be a useful method in terms of recalling different forms of memory and emotion [20]; containing multiple hand-written letters may convey more contents and context than having mere physical items; multiple USBs in a device can contain videos, visual communications and narratives from family and friends. As such, there are various approaches to improve the decoupled communication system. However, this paper prioritizes physicality and tangibility in relation to the idea of qualitative contact as the above examples may be achievable once the data transfer rate improves, for example, utilizing deep space optical communication [12]. Sending a physical contact/item to deep space would be out of scope, as these mission architectures do not include coupled supply missions.

While we can't be certain that our proposed approach is the most effective and successful method for a qualitative contact—since we have not tested it with users—we believe that our communication method, system, and tool can stimulate ideas and discussions for space habitat designs beyond today's technological solutions.

6.4 Privacy of Data Collection

Martian Delight collects data from the crew, as it needs to verify their status to release the rewards. This private information may include personal data related to health, physiology, sensory data, daily activities, among others. While this information is necessary to operate the qualitative communication system, we recognize the privacy issues involved in collecting such data [23]. In this context, we are planning to design an on/off system where astronauts can control their data sharing status. This is to prevent any unwanted and unauthorized information release during and after their long-duration space mission.

6.5 Miniaturization

Since this artifact is our first prototype, we focused on the proof of concept, and did not take miniaturization fully into account. There are various ways to miniaturize the size of the device by designing a further-optimized PCB and batteries for our next prototypes. In addition, for the device we can also consider other forms of rewarding interactions and smaller sized items as discussed earlier. Miniaturization is highly important since we are considering having more than 20 rewards/surprises in a device that can last for the long term with the crews during their deep space missions. Furthermore, space missions are resource limited. Therefore, limiting the size and mass of the object would be beneficial.

6.6 Evaluation

Ideally, we hope to evaluate and compare how different forms of rewards can influence the crew's experiences and perceptions. Here, different forms of rewards do not mean different memorable items from family or friends, but different forms of qualitative contact methods. For example, how are olfactory contact methods are different from the physical contact method in terms of the feeling of connection? Although olfactory experience is a widely known sensation that evokes/induces memories [20], how is this so different from physical phenomena that represent a certain memory in terms of user experience in the context of decoupled communication? We believe that evaluations through user testing and analysis can produce a meaningful and interesting comparative study and the findings could support our future project development.

6.7 Reward System

Rewards are crucial objects that induce learning, behaviors, choices, and emotions [22]. One of the essential methods in our communication system is that it employs a type of reward system to encourage the crew's well-being and a healthy lifestyle during long-duration/ distance space missions. Since there are different forms of reward systems—monetary, recognition, promotion, well-being and more [21][22]—and rewards are not defined by their physical properties, but by the behavioral reactions they produce—we are considering other types of reward systems for our future research to reinforce our current interaction/communication.

7. Conclusions and Future Work

Today's space habitat designs are primarily focusing on technological solutions to achieve mission success and to answer challenges related to the crew's basic physiological and psychological needs. In contrast, our study attempts to center around human-interaction, perception, and experiences, as the key aspects of advancing habitat design through user experiences. Long-duration space missions to our planetary neighbor are initially expected to have a small crew. We propose that focusing on qualitative aspects could promote various innovative opportunities, and broaden today's technological solutions. In this paper, we attempted to demonstrate how designerly processes could disrupt and contribute to space exploration and innovation in the context of deep space human connectivity and communication.

Due to the COVID-19 impact on `our research we could not fully develop and evaluate the performance of our prototype device, and carry out user studies, and assessments. Still, we wanted to open our idea and early prototype to the community to stimulate conversations, and to gain feedback and insights from fellow researchers around the world. Subsequently, we are planning to assess community feedback, and advance our prototype by employing multiple reward systems and miniaturization.

When a spacecraft travels millions of miles away from Earth to explore Mars with humans on board for the first time, we believe that such an unusual distance communication system/method could be helpful for improving the astronauts' well-being. While deep space communication is limited by the speed of light, our designerly approach introduces a new way toward the future of distance communication. What are the ways to make astronauts feel connected with their family and friends back on Earth during their long-duration space missions? Here we attempted to introduce a novel way of achieving this through the language of design by experimenting with the idea of qualitative contact and decoupled communication.

We hope that our idea may promote new ways of thinking, and stimulate further discussions around what design could do, and what design could add to future space-related innovations.

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