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MARS HABITABILITY PROJECT AT MDRS
SENSORY EXPERIENCE AND CREATIVE PERFORMANCE FOR MANNED PLANETARY EXPLORATION

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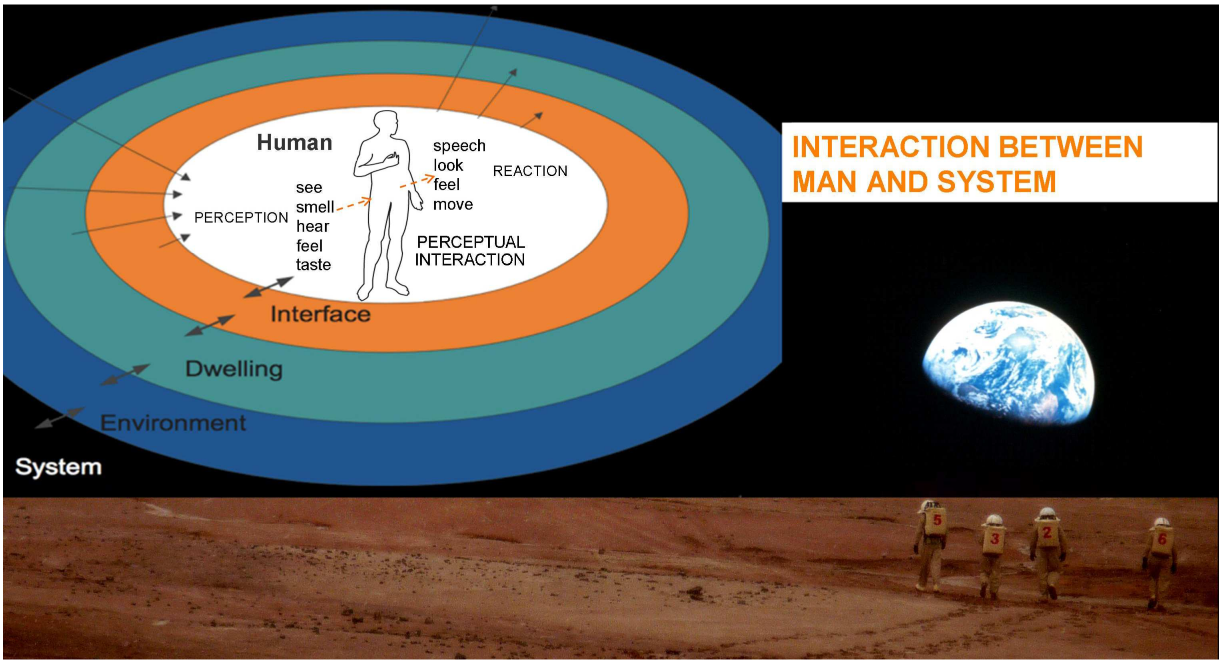
ABSTRACT: In a long duration space mission (LDM) isolation and monotony of the crew inside artificial habitats may lead to boredom, depression and lethargy. These factors impact mission safety and success. Astronauts are always required to be prepared to approach unknown problems creatively and adaptively. Sensory stimulation may enhance awareness and mental activity of the astronaut and thus counteract some of these particular stressors of the space environment.

The *Mars Habitability Project* investigates sensory stimulation and creative interaction as elements for improving habitability and safety in LDM. This ongoing project is applied in a short-duration space mission simulation context at MDRS (Mars Society Desert Research Station) and focuses on interaction with plants, colors, fragrances and sounds. The investigation, led by the research group Extreme-Design, was first conducted on 18 subjects in 2010 during the EuroMoonMars campaign upon the invitation of ILEWG (International Lunar Exploration Working Group) and SKOR (Foundation Art and Public Space). The 2010 results, based on qualitative and quantitative methodology, show a positive stimuli effect without influences on the overall subject mood.

Image1: Human Factors in Space Exploration. © I.L. Schlacht 2010 *(Earth © NASA, Perceptual Interaction © Sandra Häuplik-Meusburger, Astronauts EVA at MDRS © Schlacht)*



1. INTRODUCTION

With current technology, a mission to Mars would take around three years. In this kind of long duration mission (LDM), habitability design focuses on producing a habitat capable of supporting astronauts' research and exploration activities. Beyond the physical life support system, quality of life, satisfaction, psychological stability, performance, and mental activity are important factors in habitability design and need to be investigated (JAXA, 2009).

Habitability challenges in an isolated and artificial habitat are manifold. One is the need of standardisation and automation. Another crucial need is a functional and ergonomic stowage system. On the International Space Station (ISS), for instance, complex payloads are crammed into a small and crowded interior, restricting habitable volume, the possibility of body movement, and contributing to visual clutter. Also odour, visual clutter and noise affect habitability on the ISS as negative sensory stimulation. During isolation in an artificial context not only those 'bad' sensory stimulation but also under-stimulation (hypo stimulation) may affect habitability; the monotony of the artificial context can lead to boredom, mental lethargy and inactivity.

This paper focuses on the monotony of isolated and confined habitats, which is a common psychological stressor in LDM (Kanas *et al.* 2003). The social and environmental monotony of a confined crew in an artificial habitat will become even more relevant on a deep space mission, where the crew will not be able to closely watch the Earth from the window, a popular activity associated with orbital missions.
The hypothesis investigated in this study is that to maintain mental activity in space, crew must be stimulated as in their natural terrestrial environment. As in nature, variety is one key factor to create stimulation through unexpected and emotional experiences.
Random stimuli may be artificially planned and provide effective countermeasures against boredom. Examples may be a surprise such a gift or a change of the interior environment. The possibility of creatively and constructively interacting with the setting may also be beneficial. Indeed, humans also need to be intellectually active, continuing their learning and discovery process through constructive and stimulating experiences. Creative involvement of the astronaut may also help to alleviate boredom and to initiate mental activity. For example, some astronauts on the ISS use their free time to learn how to play a new musical instrument and may in future be encouraged to take part in other cultural activities (Triscott & LaFrenais, 2005). Such interventions and experiences should therefore be included in the planning stage of habitability design.

An ideal space habitat system should support humans' experiences and allow the active pursuit of discovery and exploration from the perspectives of both the humanities and sciences (Schlacht *et al.*, 2010). To implement such experiences in habitability design, both scientific and humanities disciplines must be involved in a holistic approach. This holistic approach (from holos, Greek for entire) aims to increase space habitability, taking into account the physical but also the spiritual needs of the user by "integrating different perspectives, such as aesthetics, emotions, instinct, creativity and cultural development, which are all considered to be relevant aspects of human space exploration**"** (Schlacht *et al.*, 2010). The experience of emotions has a "very powerful effect on memory implementing the learning factors" and individuals "tend to remember more vividly those events [associated] with a strong, pleasant emotional experience" (Vernikos, 2004). Satisfaction, contentment, relaxation, and memories are emotional experiences that can be enhanced by sensory stimulation. This is the focal concept of the *Mars Habitability Project*

1.1 Literature Review

In order to implement stimulating experiences, stimuli need to be effective culturally, creatively and emotionally, involving the astronauts actively. One of the main references is natural stimulation. The following section reviews the aspects on which the selection of color, plant, fragrance and natural sound stimuli investigated in the study was based.

Color gradation is associated with aesthetic pleasure, which is usually experienced in our daily life and in nature. Human beings have evolved in nature, and as a characteristic related to natural selection they are sensitive to the beauty of colors. For instance, indirect lighting, sunsets and rainbows have a positive psychological effect on us through the pleasure derived from the sense of beauty.
Wilson originally defined *biophilia* as "the innate tendency to focus on life and lifelike processes" (1984, p.1) and Kellert (1993) extended this idea to include that "human dependence on nature … extends far beyond the simple issues of material and physical sustenance to also encompass

human craving for aesthetic, intellectual, cognitive, and even spiritual meaning and satisfaction" (p. 20). Given that humans developed in an environment that included a variety of features supporting or harming the likelihood of survival, it follows that humans would likely prefer particular aspects of nature.

In-depth analysis of human-nature interaction provides mounting evidence that nature in the instance of plants – and by extension natural elements and specific aspects of nature (e.g. *Zen Garden*) – are restorative.
Three primary benefit domains have been identified in the empirical literature: a) physiological; b) psychological; c) social (Bates, *et al.*, 2007). For instance, Heerwagen and Orians (1986) Wise and Rosenberg (1988) found that humans prefer to look at nature-based stimuli. This is consistent with the well-established laboratory experiments, which indicate that people prefer to view landscapes with plant-life instead of built environments (Ulrich, 1979). Beyond these preferences, however, many studies are designed to detect potential benefits. In each case, positive effects have been detected. Recently, the passive and active interactions with nature have been considered simultaneously. Berman, Jonides and Kaplan (2008) compared the restorative effects of interactions with natural versus urban environments in two experiments that targeted cognitive function. Berman concluded that these results support the hypothesis that natural elements (both pictorial and "live") can have a positive impact on cognitive function.

One of the most primordial human senses, olfaction is closely related to human performance and well-being. It plays a vital role as an early sensory warning system. Olfactory intervention has been utilized in terrestrial human habitation contexts for millennia as a powerful agent of establishing identity or improving ambient conditions (Barbara & Perils, 2006). In capsule habitation, the control of volatile compounds in a closed system has been regarded as an essential aspect in relation to crew morale, such as personal hygiene and body care (Harrison, 2001; Stuster, 1986) and atmospheric integrity (NASA, 2010). In general, the senses of olfaction and gustation are diminished under reduced gravity conditions (Clément & Reschke, 2006). While space station interiors in the past have been described as musty or chemical (Zimmermann, 2003), it is acknowledged that people adapt to increasing concentrations of odours (Connors, 1985). However, particularly considering the confined setting and sensory homogeneity of spacecraft interiors in long duration missions, fragrances could provide a welcome source of stimulation. In particular, their ability to enhance food perception (Small & Prescott, 2005), evoke memories (Herz *et al.* 2003), or support alertness (Hirata, 2001; Ilmberger *et al.*, 2001) renders them an ideal supplement to psychological habitability.
The fundamentals of such 'positive' olfactory intervention and their relationship to human behaviour, performance and well-being in the spacecraft environment have been outlined by Holland and her colleagues (2004). They point out the trade-off between odor neutrality and meaningful administration of compounds according to individual preference. In support of future development of fragrance intervention to amplify other psychological countermeasures against monotony, they suggest a preliminary trial of such intervention by means of phials in a space station environment. Further development of countermeasures is also proposed by Olabi *et al.* (2002).

It is well known that music is used for psychotherapy, rehabilitation, and as entertainment increasing the well-being. There are multiple researches on music therapy using classical music (Guetin *et al.*, 2009; Harmat *et al.*, 2008; Labbé *et al.* 2007, Burns *et al.* 1999, and Blood *et al.* 1999) although there is insufficient innovative research on music and natural sound (Ono *et al.*, 2009). Kawamura (2008) compared the anti-stress effects of classical music and natural sound during bed rest. As the result of their study, it seems that classical music is more effective in reducing physiological stress, and natural sound is more effective in reducing psychological stress. Therefore, natural sound was selected to address psychological stress problems.

2. THE PROJECT

The *Mars Habitability Project* is a pilot study from the Extreme Design group, created for the Mars Desert Research Station (MDRS) in Utah where crews of six were isolated for two weeks at a time, in a simulated Moon-Mars mission.
The ongoing project investigates sensory perception and creativity for manned planetary exploration missions with the main goals of improving well-being and productivity of the astronauts, and supporting situational awareness and problem-solving skills during the mission.
Sensory stimuli such as colors, plants, sounds, and fragrance samples are selected for their

proprieties. Color gradations evoke visual pleasure and satisfaction. Plants provide tactile interaction and establish a connection with natural material stimulating feelings of pleasure. Natural sounds relax and stimulate the imagination, and fragrances evoke past experiences and memories. Additional neutral stimulus with a totally neutral and mechanical task built a reference for results comparison with creative and sensory stimulations. The mechanical task selected is copy and mirroring a surnames list *(e.g. Surname 1= 1 emanruS*). The sensory experience experiment initiated by Irene Lia Schlacht is realized with the contribution of Ayako Ono (sounds, colors), Scott Bates (plants), Regina Peldszus and Franca Stricker (fragrances).

Image 2: Mars Habitability Sensory experiences: smells, colors, sounds and plants. MDRS. © I. L .Schlacht 2010

Tasks focusing on creative performance and mood analysis are completed after the administration of the stimulus to verify if it increases creative performance.
The crew's daily life, social dynamics, schedule, and daily attitude are also recorded and investigated. Methodologies including instruments, questionnaires, interview techniques, and direct and remote behavioural observation are outlined below.

The project was first conducted during the *EuroMoonMars* Campaign 2010 at MDRS (crew 91, 92, 94; February-April) Irene Lia Schlacht was the local investigator conducting the *Mars Habitability Project* as a crewmember of crew 91 and then as supervisor of crew 92 and 94 with the collaboration of Marie Mikolajczak (Ecole de l'Air, France) and Guerric de Crombrugghe (Jump group, Université Catholique de Louvain, Belgium). The campaign was conducted with the support of the mission control, lead by campaign director Prof. Bernard Foing (ILEWG Executive Director and ESA RSSD Senor Research Coordinator), and by mission director Artemis Westenberg (Mars Society). Each crew comprised of 6 members. To validate the result with more subjects; additional research will be performed during the 2011 campaign by Ono.

Image 3: I.L. Schlacht in Extra Vehicular Activity (EVA) at MDRS. © I. L. Schlacht 2010

2.1 MDRS Habitability

The habitability analysis of MDRS is based on observation of performance of tasks, questionnaires (POMS, AttrakDiff (1) and others), interviews, AVA-IVA and social behaviour analysis, workload test (NASA TLX), heart rate measurement and collective debriefing.

The following main points negatively influenced habitability at MDRS:
- Automation & interface for system maintenance (avoid unnecessary work load and frequent errors, e.g. water tank level control).
- Storage system (difficulties for finding objects is a shared problem with ISS)
- EVA helmet visibility (must be improved to decrease frustration and to increase orientation and confidence).

From a social perspective, *crew 91* felt the need for familiarity, friendship and cohesion among the members. They conclude that knowing each other before the mission may be relevant. Some problems were due to language and cultural differences; however, these problems led to a discussion that increased crew familiarity and cohesion. As a comparison, the *Mars Habitability Experiment* was performed by *crew 94* composed of friends from the same country and university.

Crew 91 experienced positive mood and cohesion in particularly with daily food consumption and exercise activity; in particular, eating chocolate spread (Nutella ®) and performing push-up exercises with background music ("*Bring Sally Up*" from Moby) became a new social ritual.

Image 4: Crew 91 at the MDRS. © I.L. Schlacht 2010

2.2 Experiment methodology

During the *EuroMoonMars* campaign, colors, plants, sounds, and fragrance samples were tested on 11 subjects with the following procedures:

1. Mood analysis (before the stimulus)
2. Sensory experience (10 min. stimulus interaction)
3. Mood analysis (after the stimulus)
4. Creative performance task (10 min.)

The goal of the test is to stimulate sensory activity, well-being, and creativity. The subjects are able to perform the test autonomously following instructions.

The mood analysis is performed with two methodologies: the first is quantitative with a subjective rating scale on feelings, and the second was qualitative with open questions and behavioural observation.

The quantitative investigation aims to confirm mood effects, and the qualitative one to discover new effects (Howitt, 2010, p.10).

The open questions were the following:

- What is your personal opinion on the stimulus that you had?
- What is the cause of your feeling at this moment?
(i.e. I'm happy because of the sun, I'm frustrated because my PC is slow.)

The behavioural observation focused on the individual preference order in which the test was performed; in other words, each test time the subject decides with which stimuli to interact, and the chosen order is used as preference data.

The mood scale of Bond & Lader (1974) was used to assess effects on subjective mood. This scale has been used before to monitor mood and well-being of an astronaut on a short-duration space mission (Manzey *et al.*, 2000).

How do you feel now?		
Alert	❑ ❑ ❑ ❑ ❑ ❑ ❑	Drowsy
Calm	❑ ❑ ❑ ❑ ❑ ❑ ❑	Excited
Strong	❑ ❑ ❑ ❑ ❑ ❑ ❑	Feeble
Muzzy (confused)	❑ ❑ ❑ ❑ ❑ ❑ ❑	Clear-headed
Well-coordinated	❑ ❑ ❑ ❑ ❑ ❑ ❑	Clumsy
Lethargic	❑ ❑ ❑ ❑ ❑ ❑ ❑	Energetic
Content	❑ ❑ ❑ ❑ ❑ ❑ ❑	Discontent
Troubled	❑ ❑ ❑ ❑ ❑ ❑ ❑	Tranquil
Mentally Slow	❑ ❑ ❑ ❑ ❑ ❑ ❑	Quick-witted
Tense	❑ ❑ ❑ ❑ ❑ ❑ ❑	Relaxed
Attentive	❑ ❑ ❑ ❑ ❑ ❑ ❑	Dreamy
Incompetent	❑ ❑ ❑ ❑ ❑ ❑ ❑	Proficient
Happy	❑ ❑ ❑ ❑ ❑ ❑ ❑	Sad
Antagonistic	❑ ❑ ❑ ❑ ❑ ❑ ❑	Amicable
Interested	❑ ❑ ❑ ❑ ❑ ❑ ❑	Bored
Withdrawn	❑ ❑ ❑ ❑ ❑ ❑ ❑	Gregarious

Table 1: Questionnaire to rate subjective feeling from the Mars Habitability Project. (© Schlacht, 2010)

A scale from 1 to 7 is applied to rate the pairs of opposing attributes (Table 1).

Following the factor analysis from Bond & Lader, the result is grouped on the basis of three main factors:

- Factor 1 shows arousal in a scale from 1 to 7, where the value 1 implies the adjectives alert, attentive, energetic, clear-headed, well-coordinated, quick-witted, strong, interested, and proficient, and 7 implies their opposite.
- Factor 2 shows friendliness on a scale from 1 to 7, where the value 1 implies the adjectives happy, amicable, tranquil, content and gregarious, and 7 implies their opposite.
- Factor 3 shows relaxing on a scale from 1 to 7, where the value 1 implies the adjectives calm, relaxed, and 7 implies their opposite.

<table>
<tr><th colspan="3">Factors analysis variable to rate subjective feeling</th></tr>
<tr><th>MOOD</th><th>FACTORS</th><th>VARIABLE</th></tr>
<tr><td rowspan="3">1 Alert
2 Calm
3 Strong
4 Clear-headed
5 Well-coordinated
6 Energetic
7 Content
8 Tranquil
9 Quick-witted
10 Relaxed
11 Attentive
12 Proficient
13 Happy
14 Amicable
15 Interested
16 Gregarious</td><td>Factor 1 (Arousal)</td><td>1 Alert
3 Strong
4 Clear-headed
5 Well-coordinated
6 Energetic
9 Quick-witted
11 Attentive
12 Proficient
15 Interested</td></tr>
<tr><td>Factor 2 (Friendliness)</td><td>7 Content
8 Tranquil
13 Happy
14 Amicable
16 Interested</td></tr>
<tr><td>Factor 3 (Relaxing)</td><td>2 Calm
10 Relaxed</td></tr>
</table>

Table 2: Bond and Lader (1974), Factors to rate subjective feeling from the Mars Habitability Project. (© Schlacht, 2010)

3. RESULTS
3.1 Colors

This test investigates the mood effects of interacting and composing color gradations. The test used 30 transparent strips (29 cm x 4 cm) colored with decreasing saturation, so that the first part of the strip is transparent and the last part is pure plain color. By turning and rotating the strips, a very large variety of compositions are possible, and by overlapping the half-transparent strips, new colors are produced.

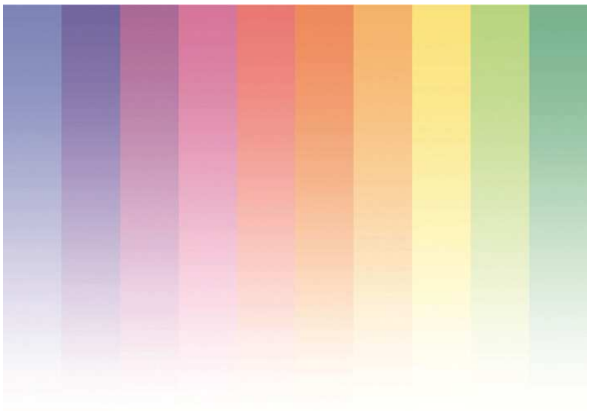


Figure 5: Color stimuli strips master from the Mars Habitability Project. (© Ono, Schlacht, 2010)

The questionnaire invited the subject to create specific color compositions. The instructions were as follows:

COLOR GRADATION (colored strips - folded A0 poster - camera). INSTRUCTIONS: 1. Use the poster as a white background. 2. With a camera, take a clear picture of the personal code that you wrote on the first page. 3. Take one clear picture of each composition you make on the white background.

C.1) On the white background, compose (3min.) color gradations (gradual shading of tint, tone, or colors into one another) using however many strips you like. Take a picture. What is the resultant color that you liked the most? ______________

C.2) Spread out the used strips into two groups (3min.): Cold (colors that give you a cold feeling); Warm (colors that give you a warm feeling). Take a picture.
What is the color that most gives you the feeling of cold ________ & warm_______?
C.3) Using however many strips you would like, make a free composition (4 min.) that matches your personal aesthetic preferences. Take a picture.
How satisfied are you:
very high I_i_i_i_i_i_i_i_i_I_i_i_i_i_i_i_i_i_I very low

Start time_______ + 10m = End time

The test goal is to verify if interaction with color may stimulate motivation, satisfaction and happiness in LDM**.**

Figure 6: Color strips composition from one crew member for the Mars Habitability Project at MDRS. (© Schlacht, 2010)

Figure 7: Color strips composition from one crew member for the Mars Habitability Project at MDRS. (© Schlacht, 2010)

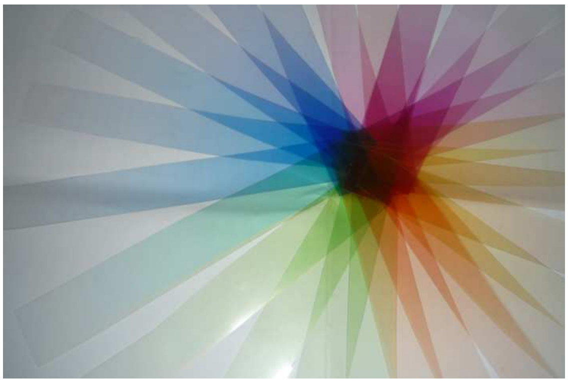
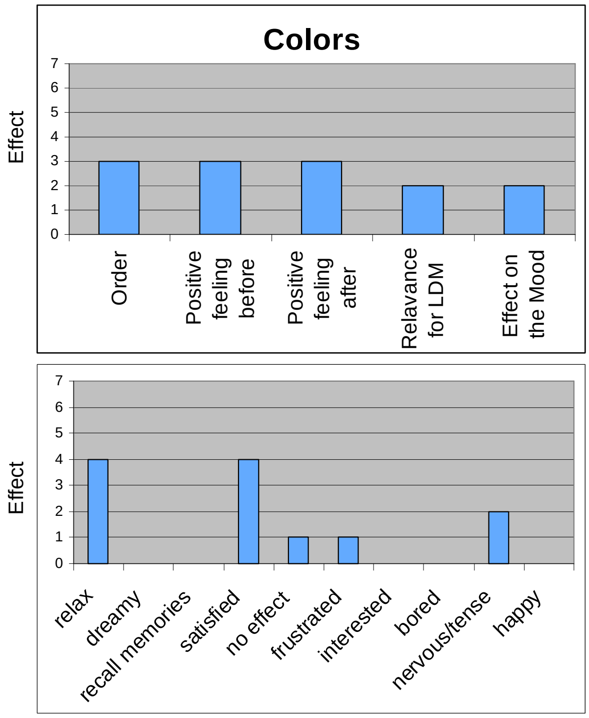


Figure 8: Color strips composition from one crew member for the Mars Habitability Project at MDRS. (© Schlacht, 2010)

The subjects performed different compositions, showing a discrete sensibility to colors.
The qualitative analysis performed on the result of 2010 shows the following effects of the colors:

- Perceived to have low relevance for habitability;
- 70% subjects reported a feeling of satisfaction after interaction with the colors.

This shows that color gradations may evoke a visual aesthetic feeling but it is not considered to increase habitability in LDM.



Diagrams 1, 2: Color test qualitative analysis for Mars Habitability Project at MDRS (© Schlacht 2010).

Following quantitative analysis of subjective feeling, it becomes clear that the color interactions do not show any relevant variation on arousal (Factor 1); slightly decrease friendliness (Factor 2) and slightly decrease the feeling of relaxation (Factor 3).

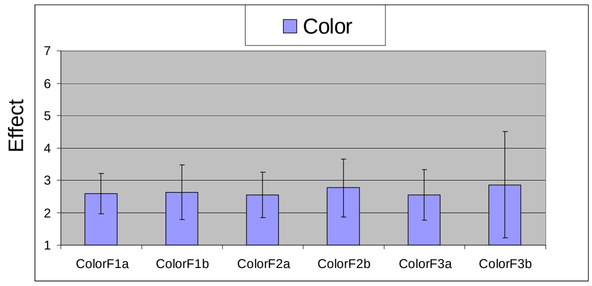


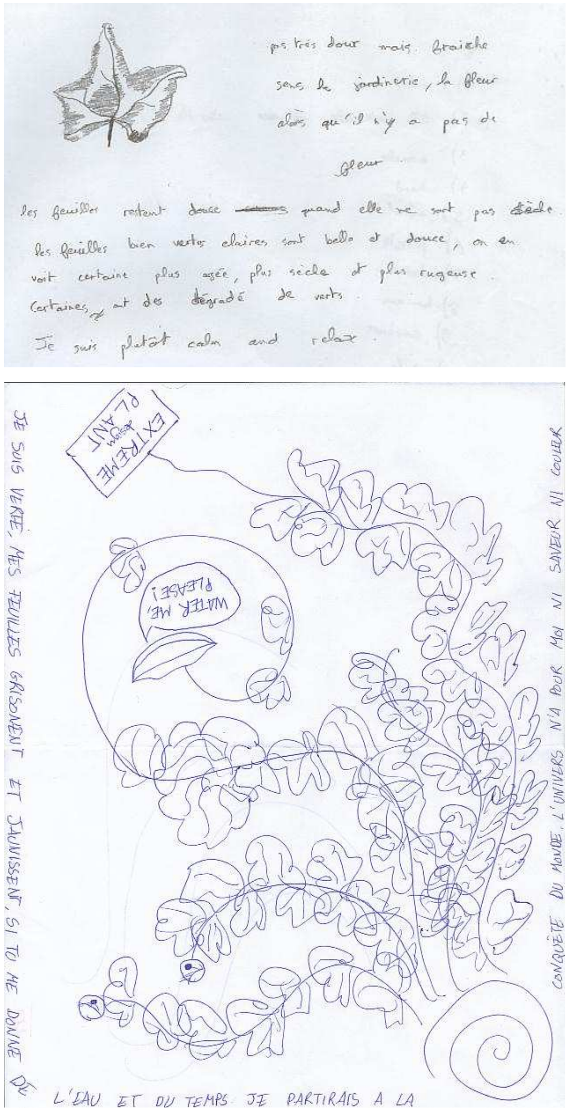
Diagram 3: Color test quantitative analysis for Mars Habitability Project. At MDRS. Index: F= Factor; a= Mean value before the stimulus; b= Mean value after the stimulus. (© Schlacht, 2010).

3.2 Plants

Originally, *aloe vera* was selected for of its low need for water, which makes it particularly practical in a space simulation. However, local restrictions did not permit the import of such plants into Utah. The test is therefore conducted with *ivy*, a generally resilient and commonly known plant that is easily obtained in Utah.

The experiment questionnaire instructions invited the subject to interact with the plants creatively and sensorially. The instructions are as follows:

PLANT (ivy plant /lierre plante)
Interact with the plant, make sketches and free notes on the A4 white paper. Please hold it, smell it, touch it. Investigate consistency, colors, shape, personal feelings, textures.
Start time_______ +10m=End time



Figures 9-10: Plants interaction result from one subject of the Mars Habitability Project at MDRS. (© Schlacht 2010).

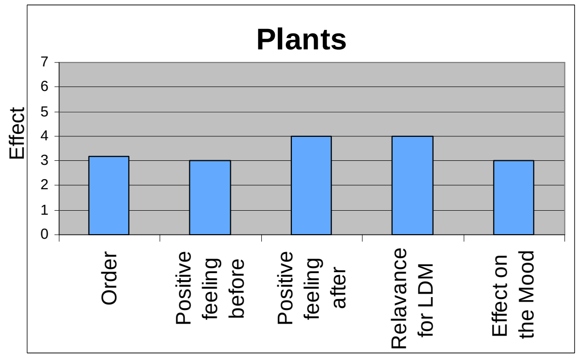
During the interaction with the plants the subjects take notes and draw about their experience.

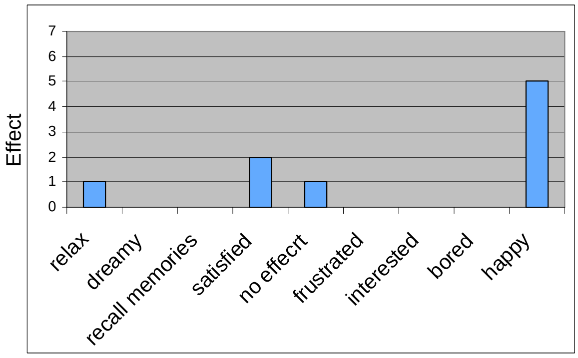
Many different results were achieved: some subjects spend more time on the interaction, and others on drawing or writing in their mother tongue or in English.

The qualitative analysis shows the following effects of the plant interaction:

- Increased positive feelings;
- 80% subjects reported to feel happy.

This confirms that plants stimulate positive feelings in confined contexts. Tactile interaction with plants stimulates both physical pleasure and feelings of well-being.





Diagrams 4, 5: Plant test qualitative analysis for Mars Habitability Project. at MDRS (© Schlacht 2010).

Following the quantitative analysis, only Factor 3 related to relaxation seems to have a slight change, tending toward the implementation of a relaxing feeling.

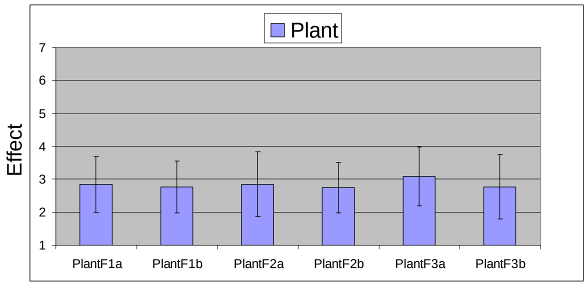


Diagram 6: Plant test for Mars Habitability Project at MDRS (© Schlacht 2010). Index: F= Factor; a= Mean value before the stimulus; b= Mean value after the stimulus

3.3 Fragrances

The study hypothesis is that olfactory stimulation evokes personal memories and can be an effective stimulant for alertness in LDM. IFF (International Flavors and Fragrances ®) samples of fragrance oils of coconut, peppermint, basil, rose 2, lime were selected for the test because they are edible, popular and easily available, and muguet as also popularly appreciate and as a contrast with the edible.

The experiment instructions invited the subject to interact with the samples administered in small containers, to analyze and test the evocative effects of the smell, and to evaluate individual preferences.

Image 11: IFF Fragrances for the Mars Habitability Project. (Peldszus, 2010, IFF London)

The detailed instructions on how the subject is asked to interact with the stimulus are as follows:

OLFACTORY FRAGRANCE (pile of plastic beakers)
You have many numbered plastic beakers, some are needed only to divide the fragrances, some contain a fragranced cotton pad.
Please, disperse the beakers with fragranced cotton pads in front of you. Please freely smell all the cotton pads. If you need to open the plastic bag, smell the cotton closely and intensively for at least 5 sec. Please smell the 6 fragranced cotton pads again before replying to all the questions.
O.1) What are the fragrances? (made of …)

_______ ___________ ______ _______ __________

O.2) Your favourite is n.____;
your second favourite is n.____;
your least favourite is n.____
O.3) What does each fragrance remind you of (3min.)?

_______ __________ ________ _________ _________

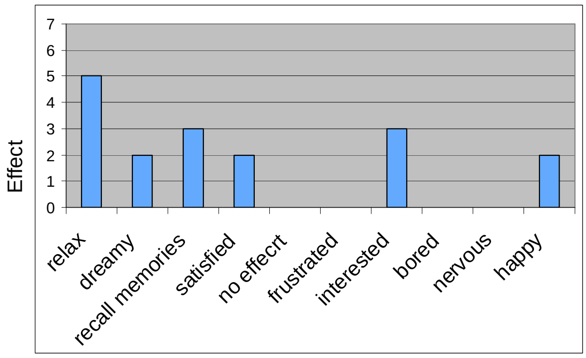
Start time_______ +10m=End time

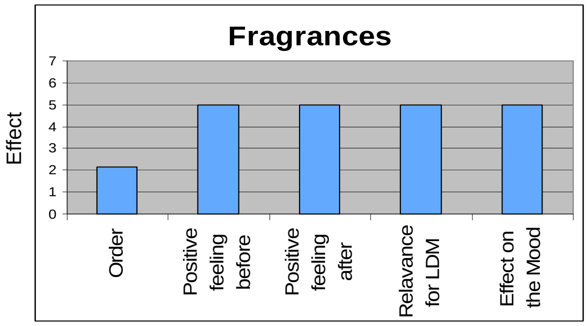
As a result, all the subjects of the 2010 session were able to recall memories after the olfactory stimulations.

The qualitative analysis shows the unexpected effects of fragrance exposure:

- The fragrance test was chosen as the last one to be performed, which shows low preference;
- After the test, it was perceived to be highly relevant to the habitability in LDM;
- 50% subjects reported to have personal memories; 100% subjects reported associations with the scents.

This suggests that fragrance intervention in space might be a useful tool to stimulate Earth-based memories.





Diagrams 7,8: Fragrance test qualitative analysis for Mars Habitability Project at MDRS (© Schlacht 2010).

From the subjective rating feeling (quantitative analysis), Factor 3 relating to "relax" seems to show mood modifications, increasing the feeling of being relaxed. Particularly interesting and unexpected is how the fragrance stimuli are considered by the crew as the most relevant to improving habitability in LDM. They also felt that the fragrances have the strongest stimulation effect.

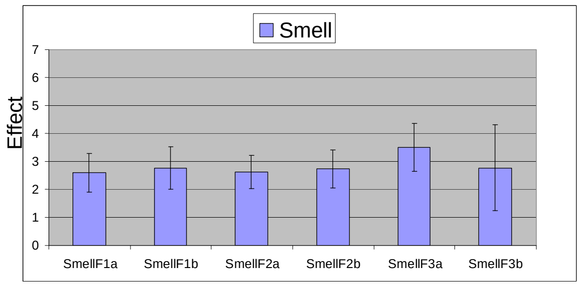


Diagram 9: Fragrance test for Mars Habitability Project at MDRS, Index: F= Factor; a= Mean value before the stimulus; b= Mean value after the stimulus. (© Schlacht 2010).

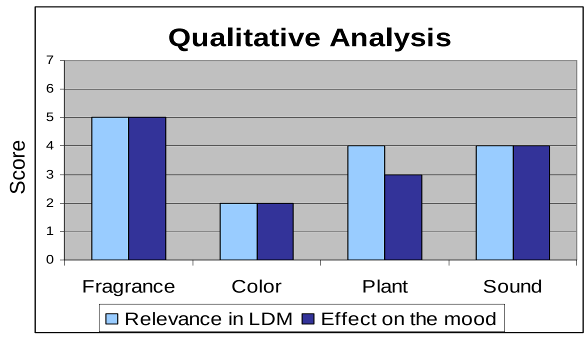


Diagram 10: Fragrance relevance for Mars Habitability Project at MDRS (© Schlacht 2010).

3.4 Sounds

Mood analyses are conducted after listening to 10 minutes of natural sounds: water streams and occasionally birds, composed and edited by Ono. To let the subject creatively interact with the sound, they are requested to take notes and draw images. The following instructions are given:

NATURAL SOUND (CD – Music player- paper- pencil) Please select a comfortable with the volume, then close your eyes, relax your body and imagine a beautiful natural environment during the sound. Listen to it for 10 min. And interact taking notes or drawing of what you perceive on a sheet of A5 paper.

S.1 Did you like listening to the birds singing? ο Yes / ο No

S.2 What was the sound in your imagination? ____________________

S.3 Were there any changes in your feelings while listening to this sound? ____________________

Start time_______ +10m=End time

During the interaction the subjects take notes and drawings about their feelings.

Again, as in the case of the plants interactions, there were many different results, some subjects take more time for the interaction, and others in drawing or writing in their native language or English. Some subjects take the opportunity to relax and free their minds. Others easily overcame their inhibitions about drawing with interesting results.

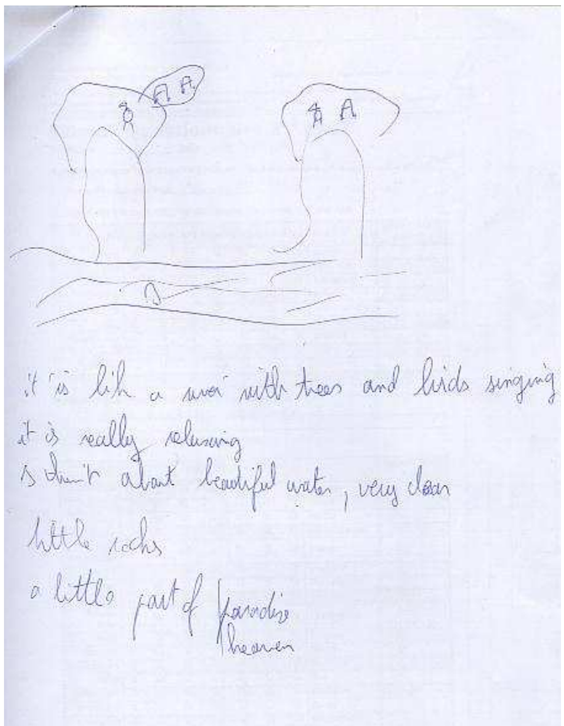


Image 12: Sound interaction result from one subject of the Mars Habitability Project, in particular this subject overcame the barrier of drawing expressing his emotion and sensations (Schlacht, 2010, MDRS)

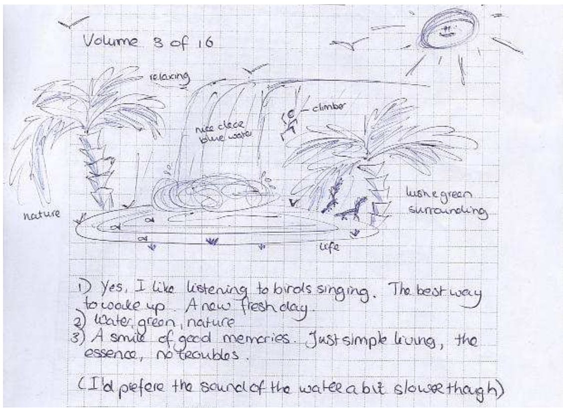


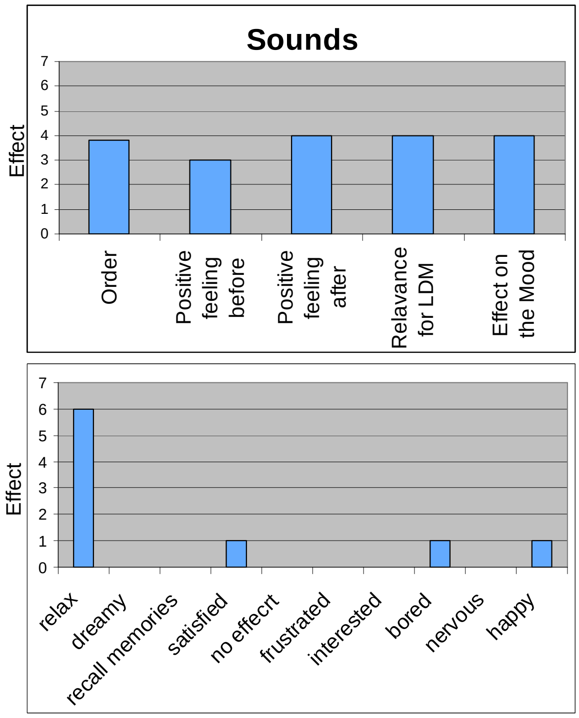
Image 13: Sound interaction result from one subject of the Mars Habitability Project. (Schlacht, 2010, MDRS)

The qualitative analysis of the 2010 results shows the following effects of the sound:

- Increased positive feeling and imagination;
- 100% of subjects felt relaxed.

This indicates that natural sounds are not only suitable for relaxation, but also that it stimulates imagination in a confined habitat.

Diagrams 11, 12: Natural Sound test qualitative analysis for Mars, Habitability Project at MDRS (© Schlacht 2010)



According to the subjective rating (quantitative analysis) Factor 3 related to "relax" seems to show mood modifications, increasing the feeling of being relaxed. However, again the quantitative results do not show any statistical relevance.

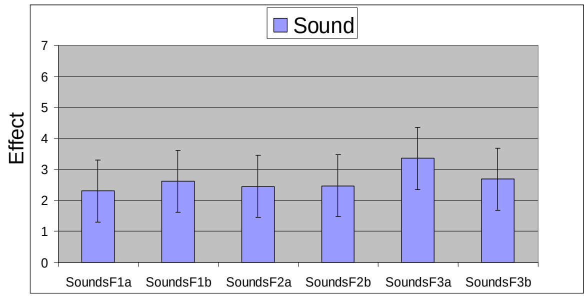


Diagram 13: Natural Sound test for Mars Habitability Project at MDRS (© Schlacht 2010). Index: F= Factor; a= Mean value before the stimulus; b= Mean value after the stimulus.

4. CONCLUSION

Astronauts are required to approach problems creatively and adaptively in space exploration. However, in long duration missions in isolation and confinement, psychological stressors can negatively affect the performance of cognitive and creative tasks.

The Extreme Design group hypothesized that a space habitat system with varied sensory and creative stimulation would result in sustained performance, well-being and reliability. This increases overall habitability and further facilitates and maintains mental activity necessary for performance of research and exploration duties.

With the *Mars Habitability Project* four types of sensory stimuli were investigated during the 2010 EuroMoonMars mission campaign simulation at MDRS. Quantitative and qualitative data were collected and the analysis showed different results.

The quantitative analysis is based on the comparison between the questionnaire on the subjective rate feeling filled in before the sensory experience and the same questionnaire filled in after the sensory experience.

The resulting value does not express a relevant effect on the overall subjective mood. In fact the Wilcox test for non-parametrical samples gives resulting values higher than 0.05. That means that the stimuli did not change the overall mood, but stimulate experiences related to these.

A neutral test of a mechanical task was performed to have a reference in comparison to the sensory experiences. The neutral test is called *mirror*, mirroring a list of surnames, affect the overall mood, decreasing happiness (Factor 2) and calm feeling (Factor 3) and decreasing alertness (Factor 1).

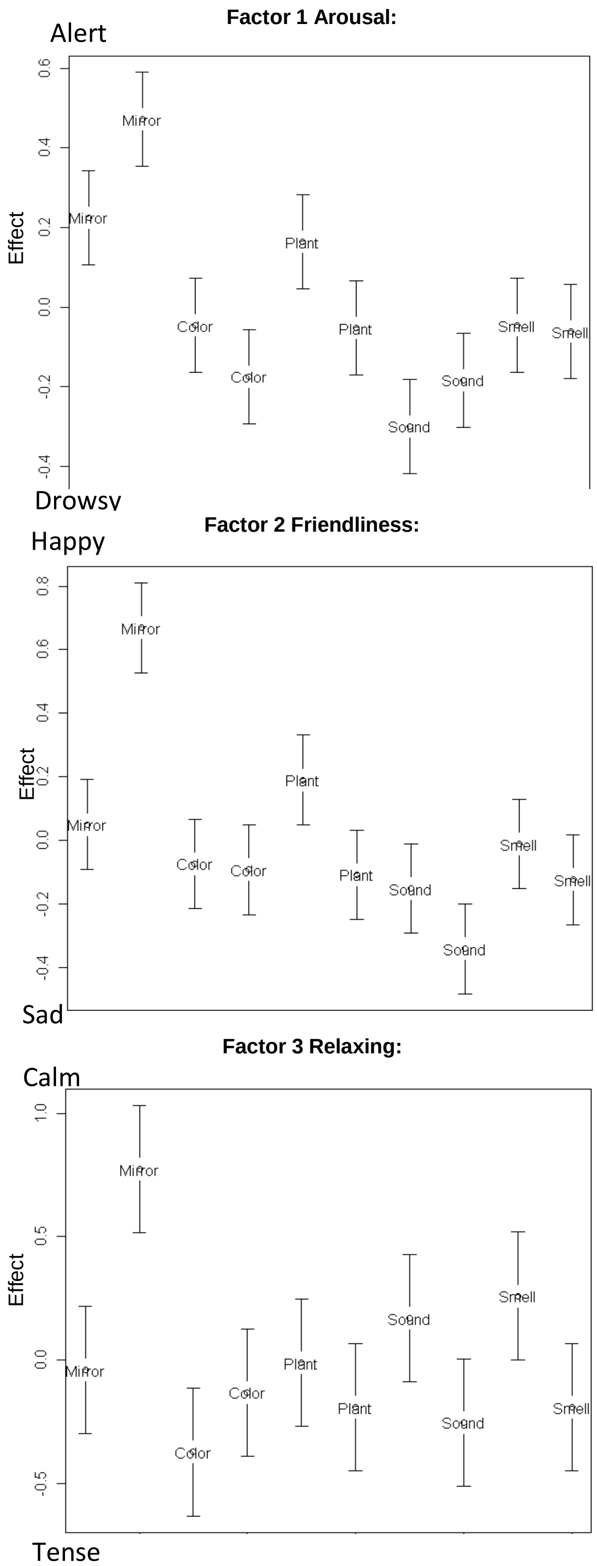


Diagram 14,15, 16: Factors error bars before and after the stimulus, referring to the quantitative analysis for Mars Habitability Project at MDRS.
The bars refer to standard errors of posterior distributions of a multivariate multilevel model in which the time and type specific effects were modelled as random intercepts. The Diagram are the result of preliminary study, verification study will be perform. (© Schlacht 2010).

The Factor 1, associated mainly with *alertness*, where alert is 1 and drowsy is 7, has a high value with the plant and color stimuli. Plants and colors have a tendency to increase a feeling of being awake also when they do not change the overall subject state.

Factor 2, related mainly to a positive and *happy* feeling, where happy is 1 and sad is 7, has low value with the plant and sound stimuli, showing that these stimuli tend to increase a positive feeling. Particularly the mechanical neutral stimulus *mirror* shows a decrease of happiness.

Factor 3, related mostly to *calm* feeling, where calm is associated with the value 1 and tense is 7, has low value with sounds and scents, showing that those stimuli tend to increase a calm feeling. Particularly the mechanical neutral stimulus *mirror* shows an increase of tenseness.

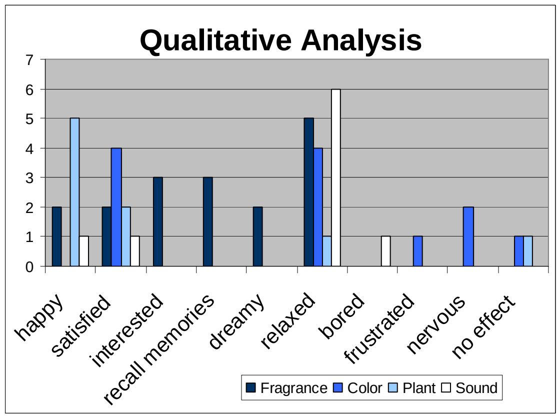


Diagram 17: Qualitative analysis of Mars Habitability experiment at the MDRS. (© I.L. Schlacht 2010)

The qualitative data show how the stimuli effect was perceived itself. The most evident effect is related to natural sound interaction for its relax effect; also evident is the memory and relaxation effect from the fragrances interaction, the positive effect from plants, and the satisfaction feeling from the color.
The stimuli were felt to be a relevant factor for LDM; particularly fragrance variation had the strongest effect and was considered relevant to habitability. This is of interest in light of the current odor neutrality requirement for ISS.
In addition to this, the *Mars Habitability Project* also increased the crew's awareness and knowledge about habitability factors and their relevance.
In long duration mission, the stimuli effect may be different, but this research provided some baseline data for further investigation.

The *Mars Habitability Project* is proposed to the MDRS Mars Society facility in Utah for the *EuroMoonMars* campaign 2011 from ILEWG.

References

Barbara, A., & Perliss, A. (2006) *Invisible Architecture: Experiencing Places through the Sense of Smell*. Milan: Skira.

Bates, S.C., Gushin, V.I., Marquit, J.D., Bingham, G., & Sychev, V. V. (2007). Plants as countermeasures in long-duration space missions: A review of the literature and research strategy. Presented at the European Space Agency Workshop: *Tools for Psychological Support.* Wilson, E. O. Biophilia. Cambridge, MA: Harvard University Press.

Berman, M.G., Jonides, J., & Kaplan, S. (2008). The cognitive benefits of interacting with nature. *Psychology Sciences, 19 (12)*.

Bond, A., & Lader, M. (1974). The use of analogue scale in rating subjective feelings. *British Journal of Medical Psychology, 47,* 211-218.

Burns, J., Labbé, E., Williams, K., & McCall, J. (1999). Perceived and physiological indicators of relaxation: as different as Mozart and Alice in chains. *Applied Psychophysiol Biofeedback, 24 (3),* 197-202.

Clément, G., & Reschke, M. (2006). *Neuroscience in Space.* New York: Springer.

Connors, M. M., Harrison, A. A., & Akins, F. R. (1985). *Living Aloft: Human Requirements for Extended Spaceflight*. Mountain View, CA: NASA.

Labbé, E., Schmidt, N., Babin, J., & Pharr, M. (2007). Coping with Stress: The Effectiveness of Different Types of Music. Published online: 27 October 2007, Springer. *Applied Psychophysiol Biofeedback, 32,* 163–168.

Guetin, S., Portet, F., Picot, M. C., Defez, C., Pose, C., Blayac, J. P., & Touchon, J. (2009). Impact of music therapy on anxiety and depression for patients with Alzheimer's disease and on the burden felt by the main caregiver (feasibility study). *L'Encéphale, 35(1),* 57-65.

Harmat, L., Taka´cs, J., & Bo´dizs, R. (2008). *Music Improves Sleep Quality in Students*. Blackwell Publishing Ltd. *JAN: Original Research,* 327-335.

Harrison, A. A. (2001). Spacefaring: The Human Dimension. Berkely: University of California Press.

Heerwagen, J.H., & G. Orians. 1986. Adaptations to windowlessness: A study of the use of visual decor in windowed and windowless offices. *Environment and Behavior, 18 (5)*, 623-639.

Herz, R. S., Eliassen, J., Belanda, S., & Souza, T. (2004). Neuroimaging evidence for the emotional potency of odor-evoked memory. *Neuropsychologia, 42 (3),* 371-378.

Hirata, Y. (2001). A study of the effective way to release scent to maintain alertness. *JSAE Review, 22(3),* 331-336.

Holland, F., Dalke, H., Matheson, M., Stott, L., & Welch, C. (2004). *Olfactory Environment Control Systems for Crewed Spacecraft, IAC-04-IAF-G.P.10*. Proceedings of the 55th International Astronautical Conference, Space Life Sciences in the 21st Century, 4-8 Oct 2004, Vancouver, Canada.

Howitt, D. (2010). Introduction to Qualitative Methods in Psychology. Pearson Harlow, England.

JAXA: Japan Aerospace Exploration Agency. (2009). Uchu igaku seibutu-gaku kenkyu ni okeru saijuhyou kadai tou (Most important action assignment in space medicine and space life science studies). Japan: JAXA.

Kanas, N., & Manzey, D. (2003). *Space Psychology and Psychiatry.* (p. 75) El Segundo, California: Microcosm Press.

Kawamura, A., Kanda, M., & Fukada, M. (2008). The Anti-Stress Effects of Classical Music and Natural Sound During Bed Rest. (In Japanese) (Vol. 31, 3). Chiba, Japan: Japan Society of Nursing Research.

Ilmberger, J., Heuberger, E., Mahrhofer, C., Dessovic, H., Kowarik. D., & Buchbauer, G. (2001). The Influence of Essential Oils on Human Attention. I: Alertness. *Chemical Senses, 26,* 239-245.

Manzey, D., Lorenz, B., Heuer, H., & Sangals, J. (2000). Impariments of manual tracking performance during spaceflight: more converging evidence from a 20-day space mission. *Ergonomics, 43*, 589-609.

NASA (2010). *NASA Human Integration Design Handbook*. Baseline January 27, 2010, SP-2010-3407. Washington, DC: NASA.

Olabi, A.A., Lawless, H.T., Hunter, J.B (2002) The effects of microgravity and space flight on the chemical senses. *Journal of Food Science, 67,* 468-478.

Ono, A., Schilacht, I., & Fukudo, S. (2009). IAC-09.A1.1.11 Countermeasures for Psychological Issues: Soundscape Design for Confined Environments. Proceedings from 60th *International Astronautical Congress*. Daejeon: Korea.

Schlacht, I.L., Argenta, M., Bandini Buti, L., Chi, Y., Ferrino, M., Masali, M., Ono, A., Rubano, F., Striker, L., & Rötting, M. (2010). Proceedings from AIAA International Conference on Environmental System 2010: *Holistic Human Factors in Space Missions.* Barcelona. Manuscript ID: 754269.R2

Small, D. M., & Prescott, J. (2005). Odor/taste integration and the perception of flavor. *Experimental Brain Research, 166* (3-4), 345-357.

Stuster, J. W. (1986). Space Station Habitability Recommendations Based on a Systematic Comparative Analysis of Analogous Conditions. Washington, DC: NASA.

Triscott, N., & la Frenais R. (eds.). (2005). *Zero Gravity: A Cultural User's Guide*. London: The Arts Catalyst.

Wise, J.A., & Rosenberg, E. (1988). The effects of interior treatments on performance stress in three types of mental tasks. CIFR Technical Report No. 002-02-1988. Grand Rapids, MI: Grand Valley State University.

Zimmerman, R. (2003). Leaving Earth: Space Stations, Rival Superpowers, and the Quest for Interplanetary Travel. Washington, DC: Joseph Henry Press.

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Her goal is to design space habitat systems using a holistic approach that includes scientific and humanistic disciplines. She can be considered a candidate expert in the field of Outer Space Human Factors.

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Image 14: EuroMoonMars Campaign team, with field scientists at ESA in the Mars simulation facilities, during the EuroMoonsMars Workshop. (Schlacht, 2010, MDRS)

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