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PI Name:	Miller, Christopher Ph.D.		
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Space Biology Special Category:	None		
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Comments:			
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Key Personnel Changes/Previous PI:			
COI Name (Institution):	Wu, Peggy (Smart Information Flow Technologies, LLC) Schmer-Galunder, Sonja (Smart Information Flow Technologies) Rye, Jeffry (Smart Information Flow Technologies) Ott, Tammy (Smart Information Flow Technologies)		
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Task Description:

Long duration missions present unique challenges to the behavioral health of astronauts. Factors such as lack of team coherence, workload, social monotony, access to family and psychosocial support, and interpersonal and cultural differences can affect both crew welfare and task performance. Metrics and methods for assessing these factors are difficult to obtain because some are inherently qualitative, while others may not be amendable to self reports. Since these factors are affected, even largely the product of, interpersonal communication, it is not surprising that interpersonal communications are our primary key to them. There are already rich sources of interpersonal communication data--both intra-crew and between flight crew and ground-- which are created and archived during International Space Station (ISS) missions. Recent research suggests that verbal and non-verbal communications can be automatically processed in a variety of ways to provide insight into team cohesion, affective and cognitive states, and team performance. Our project focuses upon the identification of suitable combinations of processing techniques (which we call "Non-Intrusive Psycho-Social State Assessors" or NIPSSAs) and data streams for assessing psycho-social states. We leverage prior work of our own and others in cultural and socio-linguistic theory to develop standardized, non-intrusive and largely automated methods for data collection and knowledge extraction of data about team interactions, relationships, and individual psycho-social states from existing data streams captured as a part of normal space operations—primarily, as determined in our first program year, verbal task interactions originating in or converted to text and personal journal entries. The created assessment technologies enable the identification and tracking of serious threats to individual and group behavioral health and task performance in order to provide empirical data with which countermeasures, training, and crew selection approaches can be systematically created to aid team performance and coherence in long duration space missions. In our first year we identified candidate assessment techniques, assessed likely data streams and desired state assessments to identify promising combinations, and prototyped and assessed these techniques on archival data representative of NASA missions and operational contexts. Last year we participated in 4 analog studies to validate these techniques on "live" data for which we also obtained concurrent survey data from participants. While we intended to study data representative of both individualized logs and interactive task communications in text, in year 2 the majority of our analyses and findings involved automated assessment of journal data. For this data type, we produced substantial validation support for our approaches, as well as a range of results pertinent to the psychological states of subjects in long term bed rest and team habitat environments.

In the third year of our project, we completed our bed rest analog study of journals kept by participants. Not only did this study produce substantial data validating several of our automated analysis techniques, it also provided data documenting novel findings about the affect and attitudes of bed rest participants, both in general and under various exercise and treatment protocols. We have shown the flexibility and rapid reconfigurability of our tools by being able to conduct novel investigations using the backlogged journal entries to answer practical questions of relevance to the bed rest study administrators and other PIs using the bed rest facility.

Also in the third year, we developed techniques for studying interpersonal task communications in the HI-SEAS (Hawaii Space Exploration Analog & Simulation) and HERA (Human Exploration Research Analog) habitat analogs. We were involved in 4 HERA missions (each 1 week in duration) and one 4-month HI-SEAS study. In all cases, we have collected journal and survey data, in conjunction with crew to ground email texts. For HERA, in addition, we have developed techniques for capturing and then transcribing crew-to-crew and crew-to-ground audio speech.

During the initial portion of a fourth year, we were engaged in data collection for portions of an 8-month HI-SEAS study and we completed processing and analysis of all data from both HERA and HI-SEAS studies, as well as cross-analog studies comparing the effectiveness of our techniques in different missions and analog environments. The results of these analyses have shown that our techniques for automatically reading and scoring elements of crew speech and/or textual communications and journals correlate significantly and reliably (over multiple missions and environments) with participant's own survey responses. This was particularly true for participant affect as measured against the Positive and Negative Affect Schedule (PANAS), a common survey instrument used to assess affect and variations in it over time. In addition, our many analyses conducted throughout this effort, are examples of the increased versatility of automated verbal processing, relative to survey instruments, as a means of assessing elements of crew affect, emotion, attitudes, and performance.

These results provide support for our general claim that non-intrusive, automated processing of text and speech could be used to replace or augment many surveys with payoffs in terms of accuracy, robustness, sensitivity and astronaut workload.

Rationale for HRP Directed Research:**Research Impact/Earth Benefits:**

The ability to non-intrusively assess individual psychological and team social states would be a huge benefit to a wide range of business and government endeavors. Systems based on our NIPSSA processing techniques could be used in many different environments where information about team interactions, relationships, and individual psycho-social states would be useful to improve behavioral health and task performance. Since the start of the program we have received interest from military agencies seeking to assess the readiness and performance of their own teams, to train military personnel in team interactions within or outside their own culture, and to assess the character and relationships of those in the enemy camp. Additionally, we conversed with marketing research and organizational management evaluation firms who wished to make use of our approaches to assess opinion leaders and team performance and have been in discussions to utilize our techniques in the area of health care teams and human-automation interaction and/or training approaches. During the prior program year, we began analysis of transcribed communications among surgical and emergency medical teams and have provided preliminary demonstrations of the ability of our leadership and "comfort/routine" NIPSSA detectors to identify valid data in these domains.

In this last program year, we have been in conversations with a large, corporate consulting firm which provides employee attitude survey data about performing automated analysis of "free text" responses within their survey instruments. We conducted a large internal research project demonstrating that tools like we have been using for NASA could be applied to their survey data to provide results that both correlate with, and greatly extend, their scalar survey questions. This demonstration is leading to a paid analysis service which we are beginning for them as of this writing.

NOVEMBER 2015 FINAL REPORT INFORMATION:

The overall objective of the AD ASTRA project (Automated Detection of Attitudes and States through Transaction Recordings Analysis, NRA grant #NNX12AB40G) was to identify suitable combinations of automated text processing techniques (which we call “Non-Intrusive Psycho-Social State Assessors” or NIPSSAs) and data streams for assessing psycho-social states of interest to NASA and to validate our overall hypothesis that NIPSSA measures could replace survey data for assessing selected psychosocial states. It had long been known that astronauts’ journals, diaries, and blogs were a rich source of material about their experiences and attitudes toward those experiences, and interpersonal communications are, after all, one of the best methods humans have of assessing changes in attitudes and states. We reasoned that if we could automate assessments of such data streams—many of which are already being captured and, to some extent, monitored during space missions—we would greatly expand the set of data which NASA team dynamics researchers have available which would help to close multiple Team and B-Med gaps and potentially improve the psychosocial health of future astronauts. Better, we could do so while concurrently improving astronauts’ daily lives and productivity by reducing the volume of surveys they are asked to complete.

The first year of our project surveyed the available techniques and data streams, arrived at the prioritization of textual analysis of journal/log entries and of interactive task discourse (in email, chat, and transcribed speech), and then went on to demonstrate promising sensitivity in the tools via analysis of pre-existing, historical data sources. While we showed individual and temporal variations with anecdotal correspondence to events, no independent data about the writers’ emotional states existed for validation of our text analysis techniques. The second year was targeted at transitioning the promising NIPSSA techniques we found with the first year’s work on historical data to validation studies with newly collected “live” data from ongoing experiments in analog environments (particularly the FARU Bed Rest Study Campaign 11 conducted at the Flight Analog Research Unit at University of Texas Medical Branch (UTMB)).

The third project year (which ended in August, 2014) was devoted to completing the bed rest analog journal study we began in Year 2, continuing to participate in a 4-month crew habitat study in the HI-SEAS (Hawaii Space Exploration Analog & Simulation) analog and beginning participation in an 8-month HI-SEAS study collecting both journal and crew-ground textual interaction messages (with corresponding survey data), and finally, developing techniques for audio data collection and then transcription in the HERA (Human Exploration Research Analog) analog, in which we obtained and analyzed journal, survey, text and speech interaction data from four separate week-long missions.

In our fourth and final, partial year (through February, 2015), we completed analyses of our HERA transcription data, and performed some cross-analog analyses illustrating the robustness of our techniques, and produced our Final Report. We were asked to take a 6 month no-cost extension by NASA personnel (through August, 2015) in which we provided a final outbriefing to NASA, prepared and submitted our data, and produced several articles. In all three analogs, we collected participant journals and daily surveys to cross validate our automated assessment techniques. In the HERA study, we also collected more than 160,000 minutes of captured audio recordings across four mission and transcribed large portions of this to enable examination of automated processing of interactive speech data.

The results have shown that automated textual analysis of subjects’ free form journals can reliably replace at least some forms of attitude and emotion surveys since our automated journal analyses regularly correlated significantly with subjects’ own survey ratings of their emotional positivity/negativity, and their focus on past/present/future across all three of our analog studies. Correlations between their attitudes about the study and about their physical well-being, as well as their focus on themselves vs. others, were also repeatedly significant. Furthermore, there is evidence that automated evaluation of journal entries may do a better job of assessing participant attitudes than do daily observers: a comparative analysis between our automated assessments and subjects’ own survey responses vs. the survey assessments of the subject by a nurse showed that automated analyses did a better job at predicting subjects’ survey responses.

We also demonstrated the speed and flexibility of our approaches by rapidly producing multiple after-the-fact analyses of elements of participants’ attitudes and emotions throughout the study including analyses of the effects of exercise and of testosterone treatments on subjects’ emotions and attitudes about sleep and food. Further, by examining the correlates of positive or negative mentions of a word group (e.g., food, eating, specific food items) we can provide suggestive evidence about how a specific individual or group thinks about that topic—e.g., that food is comforting and tied to nostalgia and social contacts or that it is a source of concern about body image and health. This flexibility to perform post hoc and deep, individualistic analyses (frequently in support of other researchers) proved to be a particularly useful capability and a strong distinguisher from survey questions.

In addition to journals, we developed techniques for examining interactive dialogue during tasks and daily activities. This form of communication is more immediate and less pre-meditated than journal entries and, therefore, is expected to be a less guarded but more transitory source of attitudes and emotions. We have detected significant differences in the overall emotional valence of the different crews, of valence for differing tasks among the different crews, and of varying (and differing) drivers for those emotional sentiments among the crew members.

During debriefs with insightful analog participants and operations personnel and throughout the 3.5 years of this program, we have identified a number of recommendations for the use of the developed techniques that are particularly relevant to long duration missions. Among these are an intervention or advisory tool for crewmembers themselves (reflecting exhibited changes in mood or attitude), a “power level” and “team comfort/routine” indicator for tracking intra-crew dynamics, and an aid for ground researchers to glean attitude and topic focus information from mission and training debriefing sessions. As recognized by the Behavioral Health & Performance (BHP) element, it will be crucial to provide accurate and low cost detection methods to detect measures relevant to BHP’s Team, BMed, and Sleep and Fatigue risks. We present data supporting the validity of ADAstra techniques as one such approach.

SEPTEMBER 2014 REPORT: The overall objective for the project is to identify suitable combinations of processing techniques (which we call “Non-Intrusive Psycho-Social State Assessors” or NIPSSAs) and data streams for assessing psycho-social states of interest to NASA. The second year of our project was targeted at transitioning the promising NIPSSA techniques we found with the first year’s work on historical data to validation studies with newly collected “live” data from ongoing experiments in analog environments. The third project year has been devoted to completing the bed rest analog journal study we began in Year 2, continuing to participate in a 4 month long crew habitat study in the HI-SEAS analog collecting both journal and crew-ground textual interaction messages (with corresponding survey data), developing techniques for audio data collection and then transcription in the HERA analog, and then obtaining and analyzing journal, survey, text, and speech interaction data from HERA missions. In further testimony to the ease,

speed, and flexibility with which data can be analyzed using our tools, we have been able to conduct novel analyses examining topics not planned for initial surveys using the bed rest journal data, and we have been among the first researchers to provide analyses of HERA crew data after each mission.

Significant accomplishments from the bed rest analog include:

1. Continued work in the bed rest analog allowed us validate several of our general techniques against survey data. These include: a. Significant correlations between our scoring of use of positive and negative emotional terms and the corresponding survey scores on the PANAS (Positive and Negative Affect Schedule) instrument. b. Significant correlations between the use of past, present, and future verb tenses in journal entries and a self-report of focus on past, present, and future. c. Significant positive correlation between mentions of a category of terms pertinent to the bed rest study in journal entries and ratings of attitude toward the survey. d. Significant negative correlation of use of terms in a category corresponding to physical state and the survey ratings of the participant's own physical state.
2. We developed novel techniques and extensions for assessing the "drivers" of attitude on an individual by combining word category use with sentiment analysis. This let us draw conclusions, for example, that one individual's use of food terms in journal entries with negative affect correlates with his use of body, physical, and health terms—which we interpret as likely indicating concerns about what the hospital diet is doing to his physique—while another uses food terms with positive affect in entries where he also uses past tense verbs and terms for social activities and family—which we interpret as likely indicating that he associates food with nostalgia for social gatherings and events. This type of insight could greatly help ground support in understanding how a psychological intervention or incentive might be interpreted by various crew members.
3. We identified an overall "positivity metric" with a potential "red line" threshold for adverse positivity expressions in journal entries, based on the work of Losada (Losada and Fredrickson, 2005), which suggests that a ratio of positive to negative utterances around 3:1 is indicative of a "thriving" individual or relationship. While this work is controversial, even discredited to some extent, and should be treated with caution, results did seem promising in our data, see below.
4. In addition to our planned analyses, we illustrated the speed and flexibility of applying our techniques (as well as the richness of journal entries as opposed to survey questions) by performing multiple auxiliary analyses which had not been anticipated in our initial experimental plan—such as on the psychological effects of exercise and testosterone treatments. These analyses were typically done in a 1-3 days of person time given our prior data set.

In addition to these validation analyses, we also were able to draw some substantive conclusions about the psychological states and the use of journals in long duration confinement conditions (for which the bed rest conditions serve as an analog). These include:

1. Although there are large individual differences, including some which countered this trend, word count of journal entries declines significantly over time.
2. Within that general trend, the proportional use of positive emotion terms, affect terms in general, perceptual terms (indicative of things being noticed or sensed in the environment), and cognitive mechanism terms (expressions of thought and reasoning) all decline significantly over time. Future tense verb use, though, increased significantly over time.
3. The analysis of positivity ratios described above showed that these ratios were correlated with trait anxiety surveys in our study and were also correlated positively with the use of terms in achievement and work categories in journal entries, and negatively correlated with use of terms indicative of health, physical state, anxiety, anger, frustration, and discouragement. Furthermore, the one subject whose ratio was below that 3:1 threshold in our sample was one who dropped out of the study.
4. Our analysis of the journals of exercisers vs. non-exercisers vs. exercisers also treated with testosterone showed:
 - a. The overall affect in journal entries (as measured by LSA valence) is higher for exercisers (in both groups) than non-exercisers. Exercisers rate (on surveys) their physical state as higher and they use physical and body terms more frequently, and with higher valence. Their valence for terms having to do with exercise is also higher.
 - b. When we discriminated between exercisers and exercisers with testosterone, however, we saw that exercise with or without testosterone clearly has substantial benefits on attitude. There was, however, no obvious added benefit from testosterone use on these fronts, over exercise alone. On the other hand, exercisers who did not have testosterone gave more positive survey responses (as opposed to our automated inferences from their journals) on explicit questions about several attitudes or behaviors than did exercisers with testosterone (who did not differ significantly from controls). Of somewhat more concern, testosterone subjects had twice the level of anxiety term usages in their journal entries as did either exercisers without testosterone or controls.
5. We did a comparative analysis between our automated assessment of subject journals and subjects' own survey responses vs. the survey assessments of the subject by a nurse who interacted with him throughout the day. These results showed that our automated analyses did a much better job at predicting subjects' survey responses than did the nurses' survey answers.

While we have completed the bed rest study of subject journals during this program year, we have also been participating in two additional studies the HI-SEAS (Hawaii Space Exploration Analog & Simulation) and HERA (Human Exploration Research Analog) habitat analogs. In neither case are analyses from these studies complete, but we have been able to develop and extend our techniques in methodological ways to enable data capture. These include:

- In the HI-SEAS study, we have collected four months of both journal and interactive email-like exchanges between crew and ground. We developed extended survey techniques to obtain data to validate analyses of inter-crew and crew-ground "familiarity" or social distance, the degree of routine vs. unusualness of a day, etc. We have also now adapted our interpersonal communications analysis techniques for power and team comfort/routine to be able to handle the data from the BaseStation software used by the HI-SEAS team to collect and sequence crew-ground communications. We have now completed an initial run of our analytic software on both journal and crew-ground interactions, but have not yet completed analysis of the results.
- We extended those survey and data collection techniques for use in the data and communications environment of the week long studies in the HERA analog. More extensively, we researched, worked with HERA facility personnel, tested,

Task Progress:

	<p>developed, and eventually deployed an approach to capturing spoken interactions between crew and from crew to ground in the analog. This approach has now been used in the first four HERA missions.</p> <ul style="list-style-type: none"> • We also developed techniques for transcribing the captured audio from HERA missions in a cost-effective fashion. This represents a substantial effort in the past 6 months as we have explored automated, semi-automated, and human transcription setups, then consulted with and evaluated multiple transcription services, and ultimately identified a specific service provider and developed a process for selecting portions of the ~40,000 minutes of audio recording produced per HERA mission which were both needed by us and the other researchers in the HERA studies, and then transcribed, formatted, and shipped those portions. <p>The results achieved during this program year now demonstrate both the viability and the validity of one class of non-intrusive psycho-social state detectors to streamline, speed and in some cases, enable, the collection of data to effectively monitor and measure team and individual health and performance fluctuations during autonomous, long duration exploration missions. For journal data, we have been successful at applying NIPSSA techniques to a variety of "live" analog settings and have shown that they correlate with traditional survey measures. We have also shown that such data is far more flexible and rich than traditional survey measures—enabling rapid, later analysis for questions not articulated or of interest during initial study development. Finally, somewhat beyond initial expectations, we are supplying data relevant to retiring BHP gaps using these NIPSSA techniques. We have designed techniques and are collecting and analyzing data from additional analog studies where we are collecting interpersonal task communications data in text and speech to enable further detailed analyses of team dynamics using similar and alternate NIPSSA techniques.</p> <p>Reference: Fredrickson BL, Losada MF (2005). "Positive affect and the complex dynamics of human flourishing." <i>Am Psychol</i> 60 (7): 678–86.</p>
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