European Space Agency
Tools for Psychological Support during Exploration Missions to Mars and Moon
ESTEC, Noordwijk, The Netherlands, 26 March 2007

ePARTNERS FOR ACCOMMODATING COGNITIVE AND AFFECTIVE LOAD OF PLANETARY EXPLORERS

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Introduction: We are developing models for hybrid human-machine systems that can cope autonomously with unexpected, complex and potentially hazardous situations. Such systems contain electronic partners (ePartners) that collaborate with the human task performers. Important goals of the partnership are to dynamically attune the task allocation and support to the available cognitive capacities and work context of operations, to improve human-machine team's resilience and safeguard human actors from failures, and to improve their self-care (mental and physical fitness). The Mission Execution Crew Assistant (MECA) project derives requirements and develops a first prototype for ePartners that assist astronauts during planetary exploration missions [1]. Each ePartner has to acquire and maintain knowledge of the (momentary) cognitive and affective load of the tasks and situation, the capacities of its human partner (hPartner) to cope with this load, and hPartner's intentions. For adequate partnership, cognitive and affective load models are needed that support shared situation awareness, trust and scrutability (i.e., the astronaut should be able to communicate with his or ePartner on its knowledge about him and the environment he acts in). This short paper presents the cognitive and affective load models that are being developed and tested for space operations in situated cognitive engineering cycles [2].

ePartner Concept: In general, an ePartner has knowledge of its hPartner with respect to his or her permanent characteristics (e.g., personality), dynamic characteristics (e.g., experience), base-line state (e.g., "normal" heart rate), momentary state (e.g., current momentary heart rate), and tasks (e.g., alarm handling). Based on this knowledge, the ePartner maintains a model of the task demands that are critical for its hPartner (e.g., the risks of cognitive lock-up in complex task situations; [3]). It will have different mitigation strategies to prevent or to diminish negative effects of human operations in such critical situations by taking over some tasks, guiding the task performance, requesting other partners to help, or subtle actions to keep the human in an adequate state (*cf*., persuasive technology, [4]).

The ePartners must have knowledge of the momentary cognitive and affective load the tasks and contexts bring about for each team member. Furthermore, they should be able to communicate this knowledge with the human team members. Therefore, we develop and apply so-called practical or "simple" theories on cognitive and affective load. Such a theory has face validity and comprises accepted features of human cognition, to be "contextualized, quantified and instantiated" for the application domain such as space missions [3]. Multimodal user-state, user-behavior and context sensing technology are used to "feed" the load models.

Cognitive Task Load: Neerincx [2] developed a model of cognitive task load (CTL) and applied it for task allocation and the design of adaptive interfaces. This model could be part of the knowledge that the ePartner has of its hPartner, distinguishing three types of cognitive load factors.

First, the ePartner should have knowledge of the time pressure. In addition to the operational and contextual demands, human's cognitive processing speed determines this pressure for an important part, that is, the speed of executing elementary cognitive processes. Particularly, time pressure is high when the processes require a lot of attention and focused concentration. Cognitive processing speed is determined by the individual capabilities to search and compare known visual symbols or patterns, to perform simple (decision-making) tasks, and to manipulate and deal with numbers in a fast and accurate way. Second, the task complexity affects the cognitive task load. Task information that is processed automatically, results into actions that are hardly cognitively demanding. Performance of routine procedures results into relatively efficient problem solving. Problem solving and action planning for relatively new situations can involve a heavy load on the limited capacity of working memory. Human's expertise and experience with the tasks have substantial effect on their performance and the amount of cognitive resources required for this performance. Higher expertise and experience result in more efficient, less-demanding deployment of the resources. Third, the CTL theory distinguishes task switching or sharing as a third load factor to address the demands of attention shifts or divergences. Complex task situations consist of several different tasks, with different goals. These tasks appeal to different sources of human knowledge and capacities and refer to different objects in the environment. Switching entails a change of applicable task knowledge.

Affective load: Affection, emotion and mood are concepts that can have many interpretations. We will use affection and emotion interchangeably to reflect a momentary state, and mood to describe a state with a longer duration. Affection comprises a broad range of feelings that humans can have and which can influence humans in their behavior. For characterizing the affective load, we focus on the underlying, often physiologically correlated factors (e.g. arousal) and map these onto distinct dimensions. Such dimensional models are helpful in both recognition and expression, as well as in models of emotion generation, in situations where sufficient data may not be available for more highly differentiated responses. Based on the Pleasure-Arousal-Dominance (PAD) model [5], we distinguish two dimensions to define the emotional state: the arousal level—low versus high—and the valence—positive versus negative. We do not distinguish a separate dominance dimension like the original PAD-model, because the dominance scale proved to explain the least variance and had the highest variability in terms of its inferred meaning in previous research.

Scenarios: For future manned space missions to the Moon or Mars, the MECA project specified a number of partnership scenarios [1]. One scenario starts with two human-machine teams, team A and B, exploring the surface at different locations. Team B is working at a large distance from the habitat, and has a relatively large rover that can carry an astronaut. At the habitat, one astronaut—Hanna—is doing her exercises following her 'self-care program'. For one member of team A, Charles, the spacesuit heater fails (figure 1). Team A, i.e. consisting of *e*Partners and astronauts, starts a fault detection and diagnosis process. Charles' *e*Partner detects the ***affective state*** "panic", predicts hypothermia and calls for help. Among other things, this message is passed on to Hanna by her *e*Partner, knowing that her ***cognitive task load (CTL)*** is OK and that her current task has low priority. However, Hanna's ***affective state*** is changing suddenly towards negative, highly-aroused. Her ePartner detects it and guides her—step-by-step—through the preparation procedures for the medical reception and treatment of Charles in the habitat. In parallel, a rover from team B received the message and offers help to transport Charles to the habitat. A Cognitive and Affective Load viewing service is used to compare the Load State of team-B members for the selection of the astronaut to provide additional assistance.

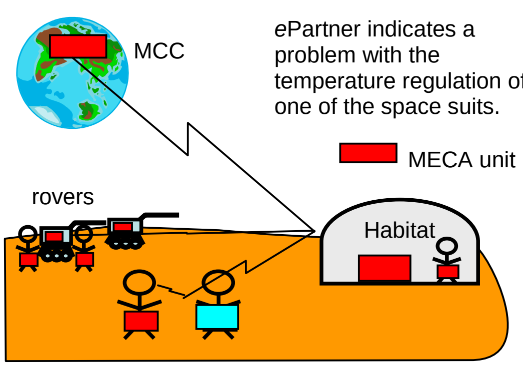

Figure 1. Example scenario state for the suit failure (MCC = Mission Control Center).

Acknowledgements: The development of ePartners for manned space missions by the European Space Agency (Contract Number 19149/05/NL/JA), in the Mission Execution Crew Assistant (MECA) project. Information is available at http://www.crewassistant.com/.

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