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Research report

Work content influences on cognitive task load, emotional state and performance during a simulated 520-days' Mars mission

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ABSTRACT

In high-risk domains such as human space flight, cognitive performances can be negatively affected by emotional responses to events and conditions in their working environment (e.g., isolation and health incidents). The COgnitive Performance and Error (COPE) model distinguishes effects of work content on cognitive task load and emotional state, and their effect on the professional's performance. This paper examines the relationships between these variables for a simulated Mars-mission. Six volunteers (well-educated and -motivated men) were isolated for 520 days in a simulated spacecraft in which they had to execute a (virtual) mission to Mars. As part of this mission, every other week, several computer tasks were performed. These tasks consisted of a negotiation game, a chat-based learning activity and an entertainment game. Before and after these tasks, and after post-task questionnaires, the participants rated their emotional state consisting of arousal, valence and dominance, and their cognitive task load consisting of level of information processing, time occupied and task-set switches. Results revealed significant differences between cognitive task load and emotional state levels when work content varied. Significant regression models were also found that could explain variation in task performance. These findings contribute to the validation of the COPE model and suggest that differences in appraisals for tasks may bring about different emotional states and task performances.

1. Introduction

Different professionals, such as police officers, military personnel, pilots and astronauts, occasionally enter high-risk situations, in which the risk for harm, information uncertainty and time pressure evoke stress in the professionals involved (Driskell & Johnston, 1998). Their job is to remain focused and perform well in these situations. Extreme levels of stress, however, can affect cognitive performances in negative ways and consequently deteriorate performances (Keinan, Friedland, & Ben-Porath, 1987; Ozel, 2001; Starcke & Brand, 2012).

Insight into human and work content factors that determine cognitive task performance in these situations are useful for finding ways to counteract the performance decline. When the influences of these factors are known, the focus of support can be placed where the help is needed. It might also allow for better anticipation for such situations (e.g., an improved human resource deployment). By monitoring the human and content variables that affect task performance, content-sensitive and personalized task support can be provided.

Based on a literature study and domain analyses, Cohen, Brinkman, and Neerincx (2012) proposed the COgnitive Performance and Error (COPE) model as a general foundation for task support in high-risk domains. In several empirical studies, this model was refined, "parameterized" and evaluated for different application domains. This paper studies the influences from different work contents on core variables of the COPE model (i.e. cognitive task load and emotional state) and the prediction of task performance based on these variables. The analysis centres around a unique experiment on human space flight: the Mars500 program[1]

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[1] www.esa.int/Our_Activities/Human_Spaceflight/Mars500.

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(i.e., a simulated complete, 520-day' Mars mission of a group of six astronauts). In the Mission Execution Crew Assistant (MECA) project, as part of the Mars500 program, the astronauts performed a set of tasks every two weeks under the stressful conditions of a long-duration mission. This experiment was set-up to refine and test the MECA requirements baseline for electronic partners (ePartners) that enhance astronaut-automation groups' performance and resilience (M. A. Neerincx, 2011; M.A. Neerincx et al., 2008; Smets, Cohen, Neerincx, Brinkman, & Diggelen, 2012). Before the study is presented, this paper will discuss the COPE model briefly and continue discussing factors that affect performances during long-term isolation missions. The Mission Execution Crew Assistant (MECA) is developing personal ePartners that regularly monitor crew-members cognitive task load and emotional states during individual and joint task performances overall mission phases (M.A. Neerincx et al., 2008). This monitoring is a joint crew-ePartner activity and the basis of envisioned ePartner support functions that should help to better cope with the social, cognitive and affective burdens mentioned above (Diggelen & Neerincx, 2010; Gorbunov, Barakova, Ahn, & Rauterberg, 2011; Hennes, Tuyls, Neerincx, & Rauterberg, 2009). The COPE-model of the next section might provide such a basis.

1.1. COPE-model

Fig. 1 shows a graphical representation of the COPE model which represents the influence of acute stress on working performances (Cohen et al., 2012). It consists of three components: work content, cognitive and affective factors, and the actions. Models have been proposed showing similar relationships between environment, appraisal and performance (Hart & Staveland, 1988; Salas, Driskell, & Hughes, 1996), the COPE model, however, includes measures of objective stress, such as physical measures, to assess and predict performance, instead of focussing merely on subjective levels and measures (Robert & Hockey, 1997; Sanders, 1983).

The COPE model distinguishes work content aspects that influence the performance under stress: The specific task *goals* and *task demands* of the work will characterize the involved cognitive and affective processes (H. J. Veltman & Jansen, 2004; J. A. Veltman & Jansen, 2003). When an individual perceives a task (i.e., the demands and goal), an assessment is made that leads to the *appraisal* of the task as either a threat or a challenge (Lazarus, 1999), and a level of *perceived task demand* which can deviate from the 'regular' task demand level.

Goals, often structured in a hierarchical way, drive the performance, but may be appraised differently (e.g., due to its relevance for a higher order goal). More challenging goals improve performance compared to easy goals (Locke, Shaw, Saari, & Latham, 1981). Tasks with different structures or characteristics might also provoke different goals and thereby show differences in task performance.

The *task demands* need to be met to complete the task successfully. Simple tasks have low task demands; more complex tasks have higher task demands. In the COPE model, (perceived) task demand corresponds to the Cognitive Task Load (CTL) measures (M. A. Neerincx, 2003). The CTL model distinguishes three load dimensions: time occupied (TOC), level of information processing (LIP), and task set switches (TSS). TOC is the fraction of the time that is actually needed to complete the task and the time that is available to complete the task. TSS is a measure for switching between tasks; in complex situations, multiple tasks need to be performed at the same time. It takes attention and effort to complete one task, and activate (i.e., start or continue with) the next. LIP is based on the levels of cognitive processes by Rasmussen (1982) and dual process theories (e.g. (Evans, 2003)). Cognitive processes can be distinguished on a continuum from analytical to intuitively. Whether someone's cognitive processing leans more towards one or the other depends, according to Hammond (1988), on the failure or success of previous judgments, and on the task characteristics. As with the cognitive processes, tasks can also be placed upon a continuum from 'inducing analytical cognition' to 'inducing intuitive cognition'.

Emotional state can be divided in three levels: valence (pleasure), arousal (energetic) and dominance (control) (Mehrabian, 1996), and is an important factor in decision making (Mosier & Fischer, 2010). Affect can be induced by the decision task itself (integral affect) or can be present beforehand (incidental affect). Incidental affect influences heuristics and the way in which information is processed (Mosier & Fischer, 2010). This type of affect also influences judgments as explained by the Affect Infusion Model by Forgas (1995).

The appraisal and perceived task demand will determine the individual's *coping strategy*. Research agrees that there are basic coping strategies that will be used when under stress, emotion-focusses and task-focussed coping (Endler & Parker, 1990) and that task-stress triggers different coping styles in different individuals (Matthews & Campbell, 1998). The chosen coping strategy, on its turn, influences how the individual reacts on the situation and

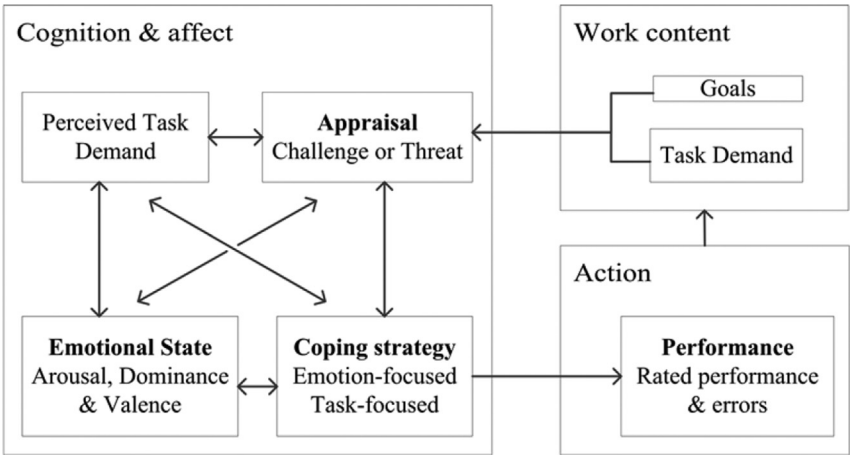

Fig. 1. Schematic view of the COPE model of work content and cognitive factors, predicting an individual's performance and errors.