Abstract

Measuring cognitive performance is crucial considering the potential implications for everyday life. The way doctors, drivers, air traffic controllers or pilots perform could affect anyone. The method to measure the quality of performance related to real-life functions is still a matter of debate, for no gold standard exists in the field. The actual main challenge in spaceflight is the organisation of long-duration manned exploration missions. Three important factors in life sciences limit the possibility to expose humans to such flights: the effects of long-duration exposure to cosmic radiations and to microgravity, and the "human factor". One of the issues at stake about this human factor aspect is the possibility to accurately measure and predict cognitive performance, in order to be able to diagnose a decrement, should it occur. To date, there is no unequivocal evidence showing a decrement in information processing during space flight. However, subjective reports of astronauts as well as real-life evidence on errors and omissions suggest the experimental reports might be underestimating potential decrements. Furthermore, in the case decrements in attention and information processing were evidenced, it would still be questionable whether they are due to microgravity *per se*, or to the "multiple stressors" hypothesis: the cumulative effect of factors including microgravity, but also increased workload, fatigue, circadian desynchronisation, confinement, and others.

The aim of this research project was to investigate the impact of operational stress on cognitive control, using both psychometric and physiological indicators. Considering the scarcity of flight opportunities, the instruments to be used and the method as a whole were repeatedly tested, and applied in ground research as well. Apart from reporting astronauts' results, the preliminary investigations on other subjects sharing the specificity of being assigned to critical functions in aeronautics -air traffic controllers, jet fighter pilots and military student pilots- are also reported.

The validation studies on the cognitive part of the methodology showed that the inclusion of emotionally loaded material in the testing had a significant impact, since this dimension showed to be most sensitive to the effects of operational stress. Furthermore, the specificity of this material, i.e. the way in which it relates to the subjects' current concerns, showed to be a critical dimension in eliciting an effect from the emotional load. In addition, the comparison of selected subjects and control groups showed that expertise can involve differences in information processing abilities, which can be measured even through tests which do not involve expertise-related stimuli. Results of these validation studies also indicated a more important effect of selection than of training and experience. The physiological measurements to be applied, namely cardio-respiratory activity, were investigated in several validation studies. Firstly, the added value of such results was demonstrated through the psychophysiological investigation of vigilance decrements. The autonomic activation recorded during the vigilance task showed that the observed cognitive decrement was paired with decreasing activation. These physiological results thus supported the "underload" hypothesis, thus allowing to settle an existing controversy regarding the origin of the vigilance decrement. Additionally, a dual physiological effect of real-life stress was identified: a higher overall activation of the subject, expressed as a higher heart rate and lower vagal tone, thus replicating the known physiological effect of stress, and, more surprisingly, a modification of the dynamic range of heart rate in reaction to additional challenge (performance of mental tasks). These findings challenge the concept of "reactivity" as an aspecific stress response, that could be elicited by any stimulation and be reliable across situations. Furthermore, this decreased reactivity due to stress was paired to failures of attentional control.

Results from the experiment during a short-duration spaceflight (3 subjects) showed that the main findings were a decreased cognitive control for emotional material, which appeared on the last data-collection before launch and on the two in-flight measurements, and the fact that this performance decrement in-flight was correlated with decreased physiological variability. These results allow us to conclude that microgravity is not sufficient to explain this pattern, thus being in favour of the "multiple stressors" hypothesis.

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Education

2006: Disaster Medicine and Crisis Management Course (Université Libre de Bruxelles).
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Career

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