INVESTIGATING HUMAN COGNITIVE PERFORMANCE DURING SPACEFLIGHT

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ABSTRACT

Although astronauts' subjective self-evaluation of cognitive functioning often reports impairments, to date most studies of human higher cognitive functions in space never yielded univocal results. Since no golden standard exists to evaluate the higher cognitive functions, we proposed to assess astronaut's cognitive performance through a novel series of tests combined with the simultaneous recording of physiological parameters. We report here the validation of our methodology and the cognitive results of this testing on the cosmonauts from the 11 days odISSsea mission to the ISS (2002) and on a control group of pilots, carefully matched to the characteristics of the subjects. For the first time, we show a performance decrement in higher cognitive functions during space flight. Our results show a significant performance decrement for inflight measurement, as well as measurable variations in executive control of cognitive functions. Taken together, our data establish the validity of our methodology and the presence of a different information processing in operational conditions.

INTRODUCTION

Reliable and remote assessment of cognitive performance is one of the crucial needs for future long duration mission planning [1]. Although astronauts' subjective evaluation often reports impairments, -to date - most studies assessing human performance could not measure any significant decrement in higher cognitive functions during space flight [2]. Cognitive performance can only be assessed through indirect measurements and no golden standard exists to evaluate the higher cognitive functions. As this discrepancy between subjective evaluation and experimental results could be methodological, we explored the possibility to maximize both the validity and the sensitivity of such testing. Potential improvements we identified were:

1. Increasing the signal-to-noise ratio of the testing. This can be reached by (i) adapting the test to the subject-population; (ii) including an emotional dimension; (iii) using multidimensional tasks.
2. Assessing an effect rather than an absolute performance (i.e. built-in control).
3. Combining physiological measurements and cognitive testing (data not shown here).

METHODS

Subjects: Students, jet fighter pilots and astronauts. The control group of pilots (N=13) was carefully matched to the characteristics of the astronaut subjects (demographics, professional background, family situation). The data collection on the astronauts was done at 6 measurement points: Launch-44 days (BDC1); L-9 (BDC2); 5th day inflight (FD1); 8th day inflight (FD2); Return+4 days (PF1); R+25 days (PF2). *Variables*: We analysed reaction times (RTs) and accuracy (Acc) for the different interference effects. *Statistical analysis*: To overcome the known problem of the scarcity of subjects in space life science research, we used routinely applied statistical methods from neuropsychology: comparing one subject to a carefully matched group of controls with revised significance criteria for the analysis of variance.

Cognitive testing: A Colour-word Stroop task, a general emotional Stroop task (presentation of emotionally loaded stimuli related to personal concerns) and a specific emotional Stroop task (presentation of mission-related emotionally loaded stimuli), in combination with a recognition task regarding the presented material, followed by a numerical Stroop task. The latter was performed before and after hyperventilation (HV).

RESULTS

Validation of our methodological assumptions: (i) Emotion can be a measurable signal through specificity and attention allocation in a normal population. As shown in Fig 2, we demonstrated a specific emotional Stroop effect in our student population (delay in RTs for emotional material, proportional to the specificity of the presented material). Furthermore, this delay in RTs is not due to a general slow down effect, but to attention allocation, as indicated by the higher discriminability (d') for specific emotional material in the recognition task (data not shown). These results support the relevance of including an emotional dimension to our experimental design.

(ii) Cognitive testing ought to be population specific. Comparing students and jet fighter pilots on the Stroop colour-word task (Fig 1) and on the emotional Stroop task (Fig 2) shows that pilots are less subject to interference from non-relevant stimulus dimensions. They were also faster and less prone to errors than students. These results indicate that highly trained and selected population (like astronauts are) should be tested through adapted tools.

Proceedings of the 9th European Symposium on Life Sciences Research in Space / 26th Annual International Gravitational Physiology Meeting, Cologne, Germany, 26 June – 1 July 2005 (ESA SP-585, August 2005)

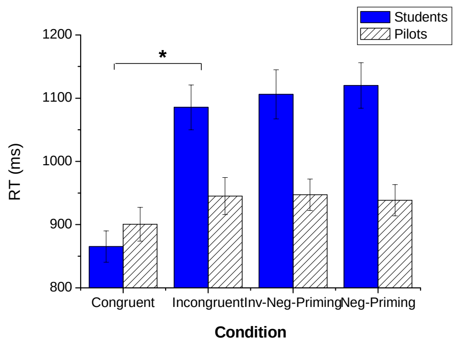

Fig 1: RTs of the Stroop Colour Word Task performed by students and pilots. The analysis of variance with "colour" as a single factor with 4 levels showed significance for students [F = 65,7; p < 0,000] as well as for pilots [F = 4,45; p< 0,005].

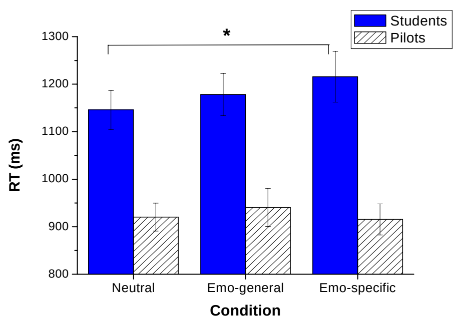

Fig 2: RTs of the Emotional Stroop performed by students and pilots. The analysis of variance with "emotion" as a single factor with 3 levels showed significance only for the students' cohort [F = 5,08; p < 0,01]. Pairwise comparisons were performed with paired samples t-tests. Only the difference between the specific emotional words and the neutral words was significant [t = 3,038; p < 0,005].

Results from the Odissea mission: Oct 29-Nov 8 2002. (i) For the last BDC and the inflight measurements, we found a significant performance decrement in response accuracy on emotional material, both personal and job-related (Fig 3).

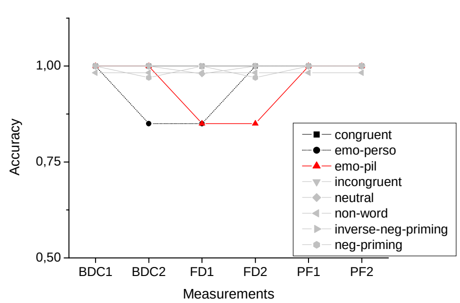

Fig 3: Acc across measurements The drop in Acc for the personal emotional material was significant for both the last BDC and the first inflight measurement [F(12) = 18,36; p<0,001]. For the professional emotional material, it showed significant for the both inflight measurements [F(12) = 20,93; p< 0,001].

(ii) We observed that the decrease in interference we measured before HV was replaced by an increased interference following HV only during inflight measurements (Fig 4). While indirectly obtained (by the imposed HV), this effect could still indicate an overall performance decrement, since it is related to a higher sensitivity to interference in cognitive processing.

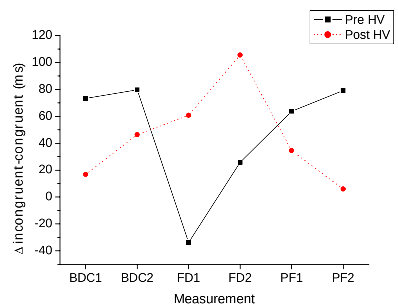

Fig 4 Magnitude of the interference effect ($RT_{incongruent}$-$RT_{congruent}$) for the numerical Stroop before and after hyperventilation (HV). The effect remains significant [F(2,22)=7,83;p<0,005] across all data points.

Discussion and Conclusion

For the first time, we show a performance decrement in higher cognitive functions during space flight.
Beside this performance decrement, our data also show a measurable difference regarding executive functions. Since there are also some effects during the last pre-flight and the first postflight measurement, the observed effects are not likely to be due to µg in se, but rather to an interaction between high workload and stress (as shown by the decrease on testing involving emotional material). Taken together, our data establish the validity of our methodology and the presence of a different information processing in operational conditions. However, future research is needed to further investigate the mechanisms at stake.

References

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Acknowledgements

Support: Prodex #90030 (ESA/BE Federal Gov't), grant RSTD# HF10 (BE DoD), an Euro Space Foundation grant.