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COGIMIR: A STUDY OF COGNITIVE FUNCTIONS IN MICROGRAVITY

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Abstract—Nonspecific (attention, psychomotor speed) and specific (mental flexibility, time estimation, visuospatial perception and memory) cognitive functions were measured in a single case study during a six day visit on the Russian orbital complex Mir using computer-based psychometric tasks. Reaction times and accuracy scores showed only minor, nonsignificant changes between preflight, flight and postflight measurements. These results suggest that several important cognitive functions, among them complex visuospatial processing skills remain essentially unimpaired during short space visits, provided that physical conditions are stable during the period of microgravity. Computerized psychometric tasks are a highly sensitive and flexible tool to measure behavioural functions in space life science.

1. INTRODUCTION

In the past two decades research programs and publications in the field of life science space research have almost exclusively been engaged in bioengineering and medical sciences. Thus, behavioural and cognitive studies of space missions have been neglected, or at least postponed to medical and physiological investigations of microgravity related effects [1]. However, visits in space are endowed with some interesting psychological aspects, and they may also induce a number of changes in behaviour and cognition [2]. The exact mechanisms leading to these changes remain to be demonstrated, all the more as the intactness of cognitive functions plays a vital and essential role in control and research activities of every space personnel. COGIMIR, a part of the cooperative AUSTROMIR project, has been developed by Austrian and Russian neuroscientists in order to study higher cognitive functions like attention, memory or visuospatial processing by means of "hard", computer-based measurements. This paper describes the methodology and some of the results of COGIMIR study to demonstrate that exact monitoring of elaborate cognitive functions during space flights is possible, even with relatively simple technical equipment, in short time and at moderate cost.

2. METHODS

2.1. Technology

COGIMIR is a computer based psychometric device based on MEL (Micro Experimental Laboratory) [3], a commercially available integrated software system for experimental research. MEL generates visual stimuli, stores experiment specifications and is equipped with an advanced system for data analysis. MEL was installed and run on the hard disk of DATAMIR (total size 3 MB). To run the experiment, subtests were choosen from a menu and then presented on a 158 × 228 mm monochrome screen. Reactions to stimuli were recorded via keyboard; on most tests only one or two keys were designated for answering stimuli.

2.2. Tests

Test designs and stimuli followed classical tasks of experimental and clinical psychology and were selected to tap several nonspecific (SREACT, CREACT, ARROWS) and specific (LINE 1, LINE 2, SPATLO, TIMEST) cognitive functions (Table 1). A central question of the experiment was whether microgravity induced altered sensory integration had any impact on visuospatial processing as assessed by LINE 1, LINE 2 and SPATLO.

Tests were presented over a 30 min period in a fixed sequence and with a short optional break before every new task. To avoid learning effects, stimuli appeared in random order. Reaction times (RT, in ms), and accuracy scores (AC, % correct) were recorded and evaluated for every single trial. During the design period, all tasks were repeatedly administered to two populations in Innsbruck and Moscow who were age and education matched to both flight candidates. Based on this pilot study, several adaptations, changes and improvements of the test

Table 1. Tests used in COGIMIR

Name	Tested function	No. stimuli	Duration (s)
SREACT	Simple reaction time	24	90
CREACT	Choice reaction time	48	90
ARROWS	Mental flexibility	48	180
LINE 1 and 2	Visuospatial perception	64	480
SPATLO	Spatial working memory	30	180
TIMEST	Time estimation	24	360
Total experiment time			23 min

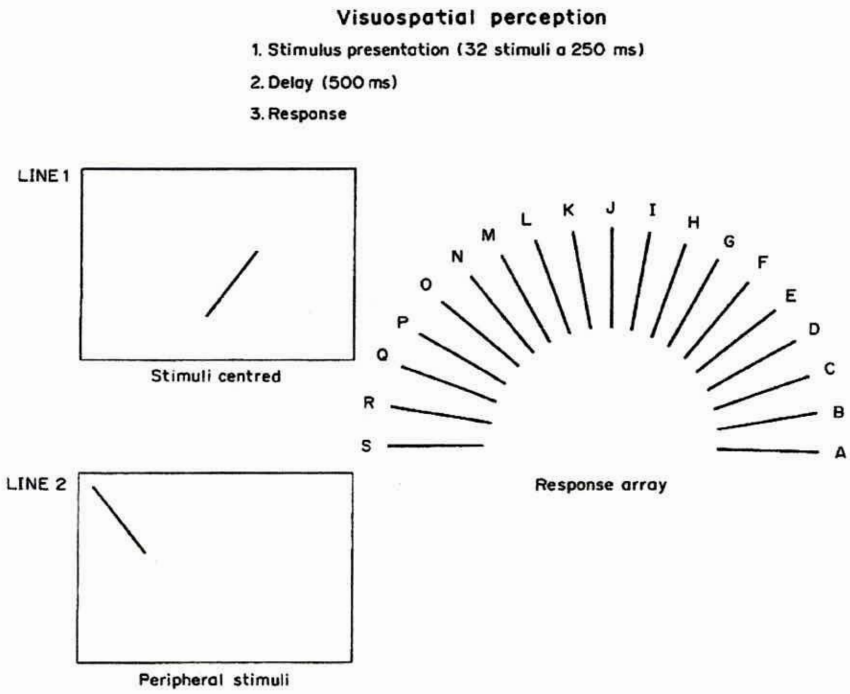

Fig. 1. Line orientation tasks (modified after Ref. [4]). Stimuli are single lines (length 25 mm) presented tachistoscopically (250 ms) in 19 different angular directions; after a delay period (500 ms) subjects respond by identifying the target line on the response array and by pressing the appropriate letter. Stimulus sequence is randomized; each stimulus is presented twice, vertical and horizontal lines (letters S, J and A) are excluded from the study.

material were made in order to assure the functionality of the final test versions and to avoid ceiling or floor effects. Stimuli, task and response procedure of experiment LINE 1 and LINE 2 (line orientation tasks) are summarized in Fig. 1.

2.3. Procedure

For the actual execution of tests both trainees were instructed to rank accuracy over speed. To reach the maximum performance level (high accuracy scores and short reaction times) both trainees (FV and CL) were made familiar with the tasks in approx. 30 test sessions over a period of 8 months. In both subjects this training increased ACs about 20–30% and reduced RTs by 60–70%. For the actual experiment a single-case sequential testing procedure (performed by FV) was used with 4 preflight, 3 inflight and 3 postflight test sessions. Preflight sessions (reference measures) were recorded on days 54, 30, 28 and 6 before the start; however, regular training sessions were continued during the preflight period. Despite the length of this recording period preflight results were homogenous documenting that FV had reached a stable condition at a high performance level. Flight sessions were performed on days 1, 3 and 6 of FV's visit on the orbital complex; postflight test dates were on days 1, 2 and 5 after landing.

3. RESULTS

All preflight, flight and postflight data were averaged; the three resulting groups were compared using a nonparametric one-way analysis of variance (Kruskal–Wallis test). Overall, there were no significant group differences on any variable. Minor performance fluctuations were recorded on several test sessions of ARROWS, SPATLO and CREACT throughout the whole experiment. On TIMEST, a tendency to underestimate longer time periods (6, 8 and 10 s) became evident on flight days 3 and 6 which continued for 2 days after landing. These fluctuations indicate trend of changing cognitive performance, they, however, did not reach statistical significance. The findings of the visuospatial perception study are summarized in Figs 2 and 3 as an example for the analysis of behavioural data.

4. DISCUSSION

Computer-based psychometric measurements obtained from the AUSTROMIR flight showed that FV's cognition remained essentially unchanged during his 6-day visit in space. Selective measurements indicated that nonspecific (attention, psychomotor performance, mental flexibility) and specific (time estimation, visuospatial processing and memory) mental abilities were performed without major changes in speed or accuracy. Inflight data revealed only slight, statistical nonsignificant fluctuations as compared to pre- or postflight state. Fluctuations in this range may be interpreted as trends of altered cognitive processing or adaptation; they also indicate that the test material of COGIMIR was sensitive to

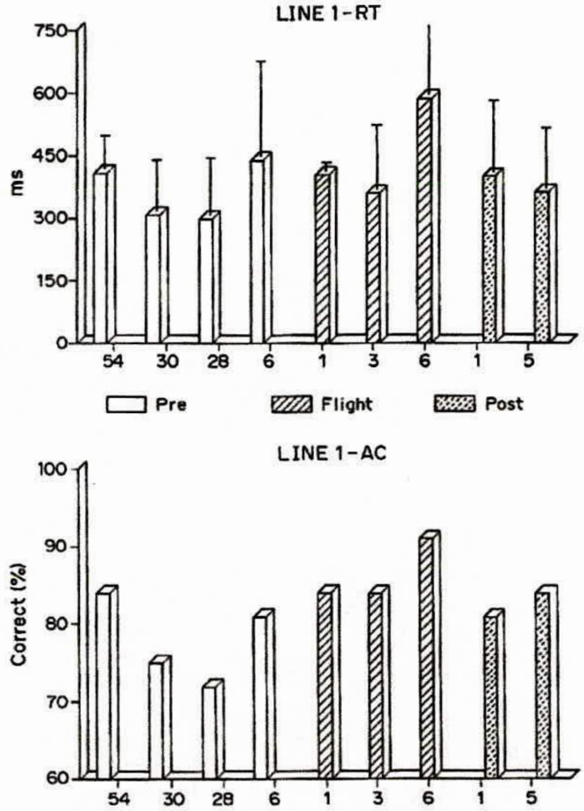

Fig. 2. Reaction times (RT, upper) and accuracy scores (AC, lower panel) of experiments LINE 1 and LINE 2. Bars represent average scores of 4 preflight, 3 flight and 2 postflight test sessions. Digits below the x-axis indicate day of testing period. Overall, RTs and ACs fluctuate only slightly during the observed periods. Noncentred stimuli (LINE 2) are processed less accurately than centred stimuli (LINE 1), whereas RTs differ only marginally between both tests. Note that proper evaluation includes the simultaneous judgement of both correlating scores (RT and AC).

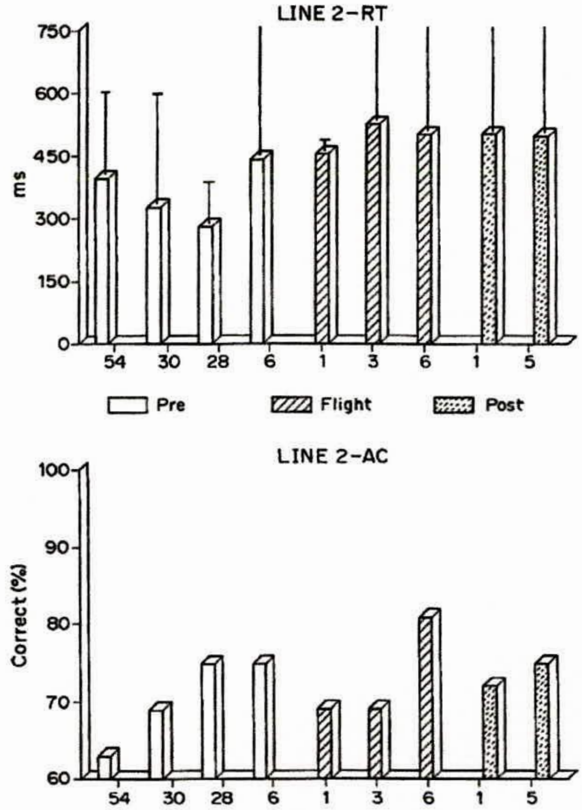

Fig. 3. As Fig. 2.

those factors of a space mission which may exert influence on cognition, among them microgravity, stress, isolation, or microgravity triggered secondary events. However, the absence of cognitive changes in this experiment can certainly not be generalized; the data amount is relatively small, was obtained in a single-case study during a 1-week flight, and collected from an all-time healthy, well trained and highly motivated subject who showed no evidence for space motion sickness. Yet, these data indicate that the present methodology, quite different from psychological questionnaires or paper-and-pencil tests, allows for an exact assessment of "hard" cognitive and behavioural data during space missions. Additional studies, especially in long-duration flights will be necessary to confirm and extend these results.

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