Results of a Long-term Computerized Self-quantification of Mental Performance, Sensorimotor Coordination and Emotional State

Vyacheslav N. Krut’ko1,2; Anna M. Markova1; Tatyana M. Smirnova1

1Federal Research Center “Computer Science and Control” of Russian Academy of Sciences, Moscow, Russia;
2Sechenov First Moscow State Medical University, Moscow, Russia

1. Introduction

To study the age-related dynamics of mental performance, sensorimotor skills and psycho-emotional state in “home laboratory” mode we conducted a longitudinal n-of-1 trial, which lasted for more than 9 years. One of us – a woman, whose age was from 54 to 63 during the experiment period – performed the self-testing. The auto-experimentation was performed with a computer system that included arithmetic and sensorimotor tasks and questionnaires, assessment of the somatic state, tone, mood and state anxiety. The data analysis showed a systemic age-related deterioration of mental performance and the self-assessment of state. The dynamics of sensorimotor skills was non-monotonic during the study. We found circadian rhythms of work capability and psycho-emotional state, and annual rhythms of sensorimotor skills. The results of individual monitoring may be used to optimize the work/rest schedules. The computer system used in the trial, may be included in the Internet environment that provides both a statistical analysis of the data accumulated by individual users with transmission of the results of data analysis to the authors, and the accumulation and analysis of large volumes of anonymous data. This approach would allow using the results of individual monitoring both for individual and family health self-management, and for quantification of performance and psycho-emotional state at the population level.

2. What We Did (and Why)?

This study was a part of our work on aging research and development of computer tools for self-testing in a “home laboratory” mode. Age-related changes of working capacity and self-perception are very important to the aging person. However, the cross-sectional studies, which are usually used in aging research, are ineffective for these processes due to high interindividual variability. Therefore, we conducted a longitudinal study, which lasted for more than 9 years. The self-testing of work capability and psycho-emotional state was carried out by one of us – a woman, who was from 54 to 63 years old in the study period; she lived in Moscow, she was a research scientist, specialist in biomedical statistics.

3. How We Did It?

The study was conducted with a “SOPR-monitoring” computer system. We have developed this computer tool for physiological monitoring in the experimental studies in space life sciences [1]. “SOPR-monitoring” system is a compact computer implementation of some test methods, which are traditionally used in space medicine. This system was used in the studies of psycho-emotional state and working capacity of:

- Volunteers in various experiments on modeling space flight factors [2, 3];
- Researchers and medical staff in their usual professional activity [3, 4];
- Elderly subjects involved in an anti-aging program [5].

The longest experiment, using this computer tool was an international project “Mars-500” – a 520-day isolation experiment which was intended to simulate a manned space flight to Mars.

Application of “SOPR-monitoring” system revealed individual and common for small groups features of the reaction to the factors of isolation, hypokinesia and anti-orthostasis (basic model factors used for simulation the spaceflight conditions), differences in sexual behavior, age dynamics of monitoring parameters according to the cross-sectional studies.

The system is very simple and reliable in use. Test duration is minimal in comparison with some other known test systems, comparable in informative value. The results of testing are recorded in a file automatically.

The test panel includes the following methods:

- “STM” test – a self-quantification of somatic state, tone and mood. The display shows a ruler with a cursor, located in...
the middle of the ruler. Two contrasting state assessments are placed on the ends of the ruler (e.g. "feeling good – feeling bad", "passive – active", "happy – unhappy"). The subject is to mark a point on the ruler corresponding to his/her state (the best state is 1, the worst state – 1). In total there are 30 questions – 10 for each of 3 scales: "somatic state" (S), "tone" (T), "mood" (M). The arithmetic mean of the 10 primary assessments is the final score for each scale.

- Arithmetic task. Digits of green, red or blue color appear in sequence in different parts of the screen for 3 minutes. The test subject has to add green digits and to subtract red digits from the previous sum with typing the result on a numeric keypad (the initial sum is taken to be equal to 0). If a blue digit appears, then the previous result is to be repeated. If the sum is entered incorrectly, then a correct answer is shown on the screen and the test subject has to enter it. A total number of operations performed (Ntot) and a number of correct answers (Ncorr) are registered and the counting accuracy (Acc), i.e. the percentage of correct answers is calculated.

- Sensorimotor task. A circle with a fixed mark and a ball, which starts moving around the circle, appears on the screen. The test subject has to press the <Enter> key every time when a mobile mark touches the fixed one. The test duration is about 3 minutes, and the ball makes 30 circles during that time. The result file contains reaction time error for each circle (if <Enter> key was not pressed at some circle, then there is a space) and calculated values – mean error (EMean), mean absolute error (EabsMean) and maximum absolute error (EabsMax).

- The State Anxiety Inventory test is a questionnaire of 20 items, corresponding to the state anxiety (SA) scale from the State-Trait Anxiety Inventory (STAI) questionnaire [6].

The test subject performed a self-testing within the period from March 2007 to May 2016 and made 190 test sessions. This study did not have a predetermined plan, therefore the intervals between test sessions ranged from one incomplete day to 286 days. Testing was carried out at different times during the breaks while working at the computer – either to perform a usual professional work or to search for information for various individual purposes.

Correlation analysis and ANOVA were used to analyze the results of home monitoring. The calculations were performed using STATISTICA package.

### 4. What Did We Learn?

The most significant correlation with the time measured from the beginning of the first monitoring session (or, with age, what is the same), was specific for counting efficiency and "STM" test (Table 1). Decrease of mental performance and self-perception may be considered as typical signs of aging. The contribution of the linear time component to the dynamics of these parameters was low. The determination coefficient $r^2$ reached 20% for no one parameter. Not only the single observations, but the mean annual values of parameters in some years rather strongly diverged from the trend line (Figure 1).

We have investigated the interrelations of monitoring parameters with the factors “time of day” and “month” (Table 1). ANOVA was performed for these factors after eliminating linear time trends from the initial values of monitoring parameters. The factor “time of day” was categorized by splitting into 2-hour intervals, beginning from 0 o’clock.

There was no correlation between the time and the parameters of sensorimotor

![Ncorr vs. Linear trend](image-url)

**Figure 1** Long-term dynamics of mental performance (M, SEM).

### Table 1 Correlation between monitoring parameters and time of registration, year of investigation, time of day, and month (see the comments in the text).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Correlation with the time of registration</th>
<th>Significance level (p) of factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
<td>$r^2$, %</td>
<td>Year of monitoring</td>
</tr>
<tr>
<td>Ncorr</td>
<td>-0.427</td>
<td>7.78E-10</td>
</tr>
<tr>
<td>Ntot</td>
<td>-0.423</td>
<td>1.19E-09</td>
</tr>
<tr>
<td>Acc</td>
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<td>0.005</td>
</tr>
<tr>
<td>EMean</td>
<td>-0.050</td>
<td>0.498</td>
</tr>
<tr>
<td>EabsMean</td>
<td>0.043</td>
<td>0.559</td>
</tr>
<tr>
<td>EabsMax</td>
<td>-0.071</td>
<td>0.330</td>
</tr>
<tr>
<td>S</td>
<td>-0.254</td>
<td>0.001</td>
</tr>
<tr>
<td>T</td>
<td>-0.178</td>
<td>0.016</td>
</tr>
<tr>
<td>M</td>
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<td>1.64E-07</td>
</tr>
<tr>
<td>SA</td>
<td>-0.033</td>
<td>0.648</td>
</tr>
</tbody>
</table>
coordination, as their dynamics was non monotone (Figure 2). A monotone growth of reaction error began in 6 years of follow-up only.

A reduction of the difference between EMean and EabsMean error proved the fact that the reaction error growth during the years 6–10 may be associated with aging. The rate of both sensory and motor reaction decreases with aging, so the contribution of delayed reactions increases and their difference during the years 1–6 of the study. Perhaps the period of irreversible aging and progressive function reduction, which any way starts earlier or later, may be preceded by a long period of function instability, at least in some individuals and for some functions.

Circadian periodicity was statistically significant for almost all monitoring parameters. Mental performance was significantly lower at night time in comparison with daytime and evening hours. Maximum mental performance was detected at 8–10 a.m. Maximum sensorimotor activities were observed within the same period, and then the reaction error dramatically grew (Figure 3). Sensorimotor coordination improved in the afternoon, and the second minimum error period was between 22 and 24 hours.

Among the parameters of psycho-emotional state, the circadian dynamics of the tone were the most evident. If the single observation within the range from 6 to 8 hours may be excluded, then the maximum value of tone was observed in the range 8–10 hours, i.e. it coincides with the maximum efficiency of both mental and sensorimotor performance. The period of evident tone slowdown corresponded to the decrease of sensorimotor skills.

Maximum anxiety levels were within the range of moderate values of this parameter (score between 31 and 45) and corresponded to the period of high mental performance, which may be a manifestation of the stress, associated with this type of activity.

The results of the study of circadian rhythms allow optimal organizing the distribution of various types of activity during a day.

The relation with the factor “month of the year” parameter was significant for all parameters of sensorimotor skills, but it was insignificant for parameters of psycho-emotional state. The most evident circannual periodicity was for sensorimotor coordination parameters (Figure 4).

The lowest level of reaction error was in the period from September to December. This result suggests that for this subject it would be reasonable to move the works requiring high reaction accuracy to this period, if possible.
The character of monthly dynamics of mental performance did not allow revealing any evident regularity. Perhaps, the lack of circannual periodicity of mental performance is due to the fact that this kind of work is the main activity of that test subject. Therefore long-term training may suppress the variability of efficiency parameters.

5. Discussion

The data analysis of a long-term self-testing with “SOPR-monitoring” system revealed some important individual characteristics of aging, performance and psycho-emotional state, which are advisable to be considered when planning work/rest schedules and building prognosis of performance. This computer tool may help a user with enough experience in the field of experimental design and data analysis, to arrange a study of mental performance under all interesting conditions and influences for himself/herself and his/her family members, and to develop optimal modes of by himself. For the users with no such training, it is advisable to complete this system with the following options:

- Advisor on planning the studies for common tasks (working capacity training with coming out to the plateau; analysis of circadian and other rhythms; analysis of age-related changes), which ensure making the recommendations on the number of test sessions required for each task and their optimal distribution in time.
- Visualization of accumulated test results in graphic form.
- Statistical analysis of data monitoring with the results, presented in tabular or graphic form and their interpretation.

These requirements can be implemented either by supplementing the “SOPR-monitoring” system with the corresponding blocks, or by including the system to Internet environment that provides both a statistical analysis of the data accumulated by individual users with the transmission of the results of data analysis to the authors, and the accumulation and analysis of large amounts of anonymous data. The second option can be implemented within the Internet system of personalized health self-management via a user's personal account. This approach would allow using the results of individual monitoring both for individual and family health self-management, and for a social-hygienic monitoring, providing a quantification of performance and psycho-emotional state at the population level.

Conflict of Interest

The authors declare no conflict of interest.

References