NEW METHOD OF VISUAL DISTURBANCES ASSESSMENT IN PILOTS DURING TESTS IN THE POLISH HUMAN CENTRIFUGE

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Abstract
Objectives: Visual disturbances are commonly accepted criteria for acceleration tolerance assessment. Researchers during centrifuge experiments use them as a safe criterion for cessation of acceleration exposure. Visual disturbances analysis is a non-invasive method of assessing retinal blood flow. Limitation of visual stimuli perception is a measure of physiological state of the experiment participants before hemodynamic changes, which reach a critical level manifested by G-induced loss of consciousness. Detection of these disturbances play an important role during the acceleration tolerance assessment. In this study, an attempt was made to answer the question on how many mistakes or incorrect reactions had to be identified to classify the ability of the pilot to fly on military jets.

Materials and Methods: A new computer-aided research apparatus of our own design was used to assess visual disturbances, being a criterion of +Gz tolerance. In the center of monitor screen, a line of 3 light points was projected. During the centrifuge test, green lateral lights randomly changed their shapes from circles to squares while central light, being a point of vision fixation, remained unchanged. To assess its efficacy, 14 volunteers participated in the tests with various stimuli exposure. The authors aimed at selecting parameters of stimuli and exposure so that the division of reactions presented in the table would correspond with the score scale appropriate for our goals.

Results: Preliminary tests showed that appropriately selected light intensity of the exposed stimuli enables the use of test results to assess the number of erroneous reactions, and consequently the level of pilots' concentration during centrifuge tests.

Conclusions: It has been found that the chosen luminance range of the projected light points is correct as it allows to evaluate the reactions, which should be considered erroneous. Additionally, prolongation of the correct reaction time to the mean value of about 400 ms facilitates better differentiation of results. Proper results evaluation, depending on the number of errors, lack of reactions or prolonged reactions made the assessment easier with computer-aided methods.

Key words: Acceleration, Visual disturbances, Research apparatus

INTRODUCTION
Visual disturbances are a commonly accepted criterion for the +Gz tolerance limit assessment during various examinations of pilots and centrifuge tests [1–3]. Determination of visual disturbances occurrence is a non-invasive technique determining eye balls perfusion during +Gz. A complete lack of light stimuli perception, manifested by the loss of consciousness, results from hemodynamic disorders, which achieve a critical level because of blood outflow from the brain vessels [4,5]. Occurrence of such disturbances during acceleration plays an important role in pilots' work.

In the 1980s, the visual field measuring device of our own construction [6] was used for tests in the Polish human centrifuge to evaluate +Gz tolerance limits (LGT). It proved efficient for several years. The device consisted of 120 light points located peripherally in the visual field (Fig. 1).

The previously performed analysis of the pilots' response to stimuli in the visual field has shown that the used com-
puter program properly differentiated pilots according to their foreseen behavior during slow-onset acceleration. Besides normal reactions too rapid or too delayed responses to the stimuli were noted. A computer-aided analysis allowed to separate them as erroneous. Data gathered this way enabled objective evaluation of pilot’s behavior under +Gz load.

However, the described visual field meter has three disadvantages listed below:

a. Exposition of light points limited to two colors only (red and green).
b. Lack of equality in light intensity of individual light points.
c. Impossible changes in the light intensity and background color as well as in the shape of light stimuli.

The introduction of a new centrifuge test program with rapid-onset +Gz required a detailed determination of LGT, especially in pilots of high performance aircrafts [7,8]. Too rapid onset of +Gz causes G-LOC (G-loss of consciousness) appearance without usually preceding visual disturbances. The question is: to what rate of +Gz onset this criterion can be used?

The need to change the stimuli exposure system for pilots’ field of view has emerged. Therefore, it was necessary to design and incorporate a novel system for visual stimuli presentation.

The aim of this work was to establish proper visual stimuli parameters in stationary conditions. Further works will be aimed at extending visual parameters testing under various acceleration profiles.

MATERIALS AND METHODS

The basic element of the visual presentation system is a “color 42” flat plasma monitor placed in the centrifuge cockpit in front of the pilot (Fig. 2).

The function and capabilities of the visual presentation system are listed below.

a. Random change of the extreme light points shape is produced in the prefixed by the operator time interval from 1 ms to 10 s with resolution of 1 ms.
b. Change of the extreme light points shape is time programmable by the operator in the range from 1 ms up to 10 s with resolution of 1 ms.
c. System enables an introduction of both maximum and minimum allowable time of the examined pilot reaction with resolution of 1 ms.
e. Distance between the extreme light points and lateral edges of the active screen field is variable and regulated by the operator within the whole range of screen width.
f. Diameter of the extreme light points can be programmed from 20 mm to 100 mm.
g. Diameter of the central light point (stimulus) may vary from 50 mm to 400 mm.
h. Light points are projected on the screen in the horizontal line and its localization may be regulated.
i. Color, brightness, and contrast of all light points and the background are regulated and may be changed by the operator in the range of operational system capacity of the plasma monitor steering computer.

j. System enables to save projected image configuration.

k. System is protected against the entry of an erroneous configuration.

l. System enables to register records containing information on the reaction of the examined pilot with its evaluation. It is presented on-line on one of the screens in centrifuge steering room. If there is no reaction from the examined pilot, number “999” is recorded together with the assessment of reaction time, describing its lack or prolonged time; in the record, sign “!!!” appears. If the reaction time is shorter than that predetermined in the configuration file, the real time is recorded with the remark: “too early reaction” and sign “???” appears in the transmission record. If the reaction time is within predetermined limits, it is recorded as correct reaction (sign “---”).

The examined pilot, having seen a change of lateral light points shape, presses an appropriate button on joystick of the F-16 aircraft, placed in the centrifuge cockpit. A lapse of time between notification of the change in light points shape and pressing the button is a measure of reaction time to the presented light stimulus. Prolongation of this reaction time or the absence of reaction to presented stimuli confirms narrowing of the visual field. Complete lack of reaction to peripheral stimuli informs the physician who carries the test about narrowing of the visual field below the angular distance between two extreme light points.

Computer-aided recording of the reaction time enables to evaluate the pilot’s behavior. It facilitates an assessment of the concentration degree, speed of reaction, and activity under the condition of rapidly increasing hemodynamic disorders.

Fourteen volunteers, aged between 24 and 35 years, were examined in the immobile cockpit of the human centrifuge. Three light points were projected on the white screen. The diameter of the peripheral light points was 30 mm and the distance between them was 912 mm. The central point of sight fixation was 80 mm in diameter; its color was green whereas peripheral points were red. The shape of constantly projected points was circle while their change into squares — stochastic.

After a 10-min adaptation to the cockpit illumination, the program of stimuli exposure started. The examined individual responded to them for 30–60 s. Projected stimuli appeared in the stochastic manner and their rhythmic following was difficult. The aim of this phase of the study was to acquaint the examined pilots with the reaction to changes of projected stimuli. Time of this training was dependent on the learned correct reactions and appropriate concentration degree. After a 2-min rest, basic examination started and lasted for 3 min. During that time, about 60 changes of the peripheral stimuli shapes were projected, to which the examined pilots had to react correctly.

Optimum presentation of the light stimuli for centrifuge tests was established with several measurements of projected light points brightness and time of reaction. Luminosity of all points present in the centrifuge cockpit was measured with a luxmeter SONOPAN Type L-100 equipped with the PL 1.RF-100 luminance measuring unit.

RESULTS

Luminosity (cd/m²) of the cockpit, monitor, and exposed stimuli prior to and after luminance changes are shown in Table 1.

<table>
<thead>
<tr>
<th>Measurements</th>
<th>Cockpit illumination (lx)</th>
<th>Monitor luminance (cd/m²)</th>
<th>Brightness of the light points (cd/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>peripheral</td>
</tr>
<tr>
<td>Baseline</td>
<td>63.2</td>
<td>67.6</td>
<td>64.7</td>
</tr>
<tr>
<td>After the change</td>
<td>35.0</td>
<td>50.0</td>
<td></td>
</tr>
</tbody>
</table>

Reaction time of the examined pilots after the change of projected stimuli brightness are shown in Table 2.

Our aim was to obtain such a distribution of results so that an evaluation of the examined pilots’ behavior during +Gz could be possible. Rejection of 10% of extreme results, i.e. too short or prolonged reactions, enabled to properly cal-
calculate the mean value of the correct reaction time. Moreover, it enabled a computer-aided analysis of normal and abnormal reactions. Comparison of the mean reaction time distribution with the aid of visual field meter after the change of stimuli brightness showed statistical significance (p = 0.003). The data analysis showed that the decrease in stimuli brightness, projected on the monitor screen, was the prolonged reaction time of the examined pilots. Absolute difference of the mean reaction time was 27.807, i.e. reaction time was prolonged (Table 1).

A decrease in luminance exerted an effect on the reaction time. It enabled the assessment of the examined pilots' reactions according to our own experience with thousands of centrifuge tests with use of the earlier version of visual field meter. Change of the projected stimuli brightness in the new version enabled the following assessment of the results obtained. Reaction time shorter than 200 ms was considered to be too early and probably accidental. Such reactions were considered erroneous in the computer-aided analysis. Another problem was related to prolonged reactions to the change of stimuli. It was assumed that reactions of over 800 ms may be considered prolonged, even if they were in the range of time limits before appearance of the consecutive stimulus. However, such reactions exerted the effect on the pilots' behavior under acceleration load. Baseline reaction times proved to be too short and thus a more precise assessment of reaction of extreme parameters, i.e. too quick or prolonged, was difficult. Changes in the luminosity of the exposed stimuli (i.e. decreased brightness of the peripheral and central light points) was introduced to obtain a desired distribution of the examined pilots' reactions.

### CONCLUSIONS

It has been found that:

1. Chosen luminance range of the projected light points is correct as it enables to evaluate these reactions, which should be considered erroneous.
2. Prolongation of the correct reaction time to the mean value of about 400 ms enables better differentiation of results. Proper results evaluation, depending on the number of errors, absent reactions or prolonged reactions was then easier to assess with computer-aided methods.

### REFERENCES